Calibration of the Biological Condition Gradient (BCG) for Fish and Benthic Macroinvertebrate Assemblages in the Northern Piedmont region of Maryland

FINAL REPORT

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EXECUTIVE SUMMARY

The objective of the Clean Water Act is to “restore and maintain physical, chemical and biological integrity of the Nation’s waters.” To meet this goal, we need a uniform interpretation of biological condition and operational definitions that are independent of different assessment methodologies. These definitions must be specific, well-defined, and allow for waters of different natural quality and different desired uses. The US EPA has outlined a tiered system of aquatic life use designation, along a gradient (the Biological Condition Gradient, or BCG) that describes how ecological attributes change in response to increasing levels of human disturbance. The Biological Condition Gradient is a conceptual model that describes changes in aquatic communities. It is consistent with ecological theory and has been verified by aquatic biologists throughout the United States.

Specifically, the BCG describes how ten biological attributes of natural aquatic systems change in response to increasing pollution and disturbance. The ten attributes are in principle measurable, although several are not commonly measured in monitoring programs. The gradient represented by the BCG has been divided into 6 BCG levels of condition that biologists think can be readily discerned in most areas of North America, ranging from “natural or native condition” (level 1) to “Severe changes in structure and major loss of ecosystem function” (level 6).

This report summarizes the findings of a panel of aquatic biologists from the Montgomery County Department of Environmental Protection, the Maryland National Capital Park and Planning Commission, the State of Maryland Department of Natural Resources and the Department of Environment, the University of Maryland, the University of Maryland at Baltimore County, the Interstate Commission for the Potomac River Basin, US EPA and the states of Virginia, Pennsylvania and Delaware, who applied and calibrated the general BCG model to streams in the Northern Piedmont ecoregion of Maryland. The panel was challenged to 1) assign Biological Condition Gradient attributes to vertebrate (fish and salamander) and invertebrate species recorded in the dataset and 2) to achieve consensus in assigning stream reaches into BCG levels using the fish/salamander and invertebrate assemblage data. The rules used by the panelists were compiled, tested, and refined, and vetted with the panel through a series of meetings and conference calls. The end products were 4 quantitative BCG models to predict the BCG level of a stream based on the rules developed by the panel (1 for invertebrates and 3 for fish/salamander, based on stream size - small (0.5 to 1.4 mi^2), medium (1.5 – 7.9 mi^2) and large (> 8 mi^2)). The invertebrate panel assessed 46 calibration samples and 14 confirmation samples that were not used in the calibration step. The BCG invertebrate model correctly assessed 95.7% of the calibration samples and 92.9% of the confirmation samples. The BCG fish/salamander panel assigned 52 samples to BCG levels during the calibration exercise and assessed 13 more during the confirmation round. The BCG fish/salamander models correctly assessed 100% of the calibration samples and 92.3% of the confirmation samples. The Northern Piedmont BCG models can potentially be used to supplement traditional community data analysis used for water quality assessments.

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The participants in this effort invested significant time and commitment in the process. We are grateful for their hard work and enthusiasm.

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ACRONYMS

BCG	Biological Condition Gradient
CWA	Clean Water Act
IBI	Index of Biological Integrity
MBSS	Maryland Biological Stream Survey
MDDNR	Maryland Department of Natural Resources
MO DEP	Montgomery County Department of Environmental Protection
MNCPPC	Maryland National Capital Park and Planning Commission
TALU	Tiered Aquatic Life Use
TMC	Ten Mile Creek Watershed
US EPA	U. S. Environmental Protection Agency

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1 INTRODUCTION

This document describes the calibration of assessment models in the framework of the Biological Condition Gradient (BCG) for streams in the Northern Piedmont ecoregion of Maryland. Models were developed for macroinvertebrate and fish/salamander assemblages. The models incorporate multiple attribute decision criteria to assign streams to levels of the BCG. The models were developed using data from the Montgomery County Department of Environmental Protection (MO DEP) and the Maryland Department of Natural Resources (MDDNR) Biological Stream Survey program (MBSS). Participants included scientists from the MO DEP, the Maryland National Capital Park and Planning Commission (MNCPPC), the State of Maryland Department of Natural Resources and the Department of Environment, the University of Maryland, the University of Maryland at Baltimore County, the Interstate Commission Potomac River Basin, US EPA and the states of Virginia, Pennsylvania and Delaware. The Northern Piedmont BCG models can potentially be used to supplement the Index of Biological Integrity (IBI) measures that MO DEP and MDDNR currently use to assess stream health.

1.1 Why Is Measuring Biological Condition Important?

People care about the biota that live in their waters. A natural aquatic community and a surrounding, intact watershed provide many social and economic benefits such as food, recreation and flood control. The US Clean Water Act reflects this public priority by establishing the national goal to restore and maintain the chemical, physical and biological integrity of the Nation's waters.

Biological assessments can be used to directly measure the overall biological integrity of an aquatic community and the synergistic effects of stressors on the aquatic biota residing in a waterbody (Figure 1). Biological assessments are an evaluation of the biological condition of a waterbody using surveys of the structure and function of resident biota. The biota functions as a continual monitor of environmental quality, increasing the sensitivity of our assessments by providing a continuous measure of exposure to stressors and access to responses from species that cannot be reared in the laboratory. This increases the likelihood of detecting the effects of episodic events (e.g., spills, dumping, treatment plant malfunctions), toxic nonpoint source pollution (e.g., agricultural pesticides), cumulative pollution (e.g., multiple impacts over time or continuous low-level stress), nontoxic mechanisms of impact (e.g., trophic structure changes due to nutrient enrichment), or other impacts that periodic chemical sampling might not detect. Biotic response to impacts on the physical habitat such as sedimentation from stormwater runoff and physical habitat alterations from dredging, filling, and channelization can also be detected using biological assessments.

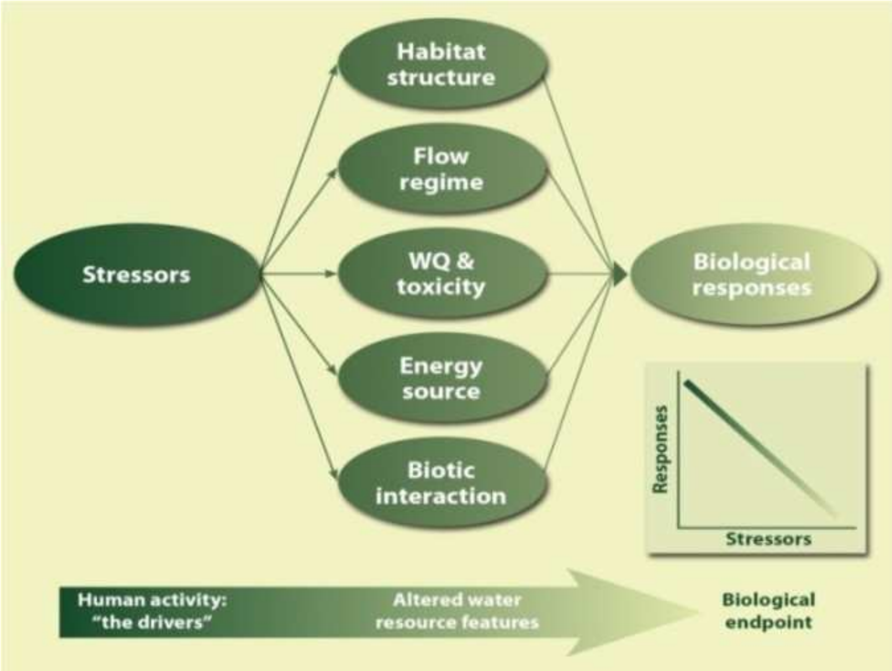

Figure 1. Biological assessments provide information on the cumulative effects on aquatic communities from multiple stressors. Figure courtesy of David Allen, University of Michigan.

1.2 The Biological Condition Gradient

The Biological Condition Gradient (BCG) is a conceptual, narrative model that describes how biological attributes of aquatic ecosystems change along a gradient of increasing anthropogenic stress. It provides a framework for understanding current conditions relative to natural, undisturbed conditions. Some states, such as Maine and Ohio, have used a BCG framework to more precisely define their designated aquatic life uses, monitor status and trends, and track progress in restoration and protection (US EPA 2011a). These two states and many others have used biological assessments and BCG-like models to support water quality management over several decades. Based on these efforts, US EPA worked with biologists from across the United States to develop the BCG conceptual model (Davies and Jackson 2006.) The BCG shows an ecologically-based relationship between the stressors affecting a waterbody (the physical, chemical, biological impacts) and the response of the aquatic community, manifested as the biological condition. The model can be adapted or calibrated to reflect specific geographic regions and waterbody type (e.g., streams, rivers, wetlands, estuaries, lakes). Approaches to calibrate the BCG to region-, state-, or tribe-specific conditions have been applied in several ecological regions by multiple states and tribes.

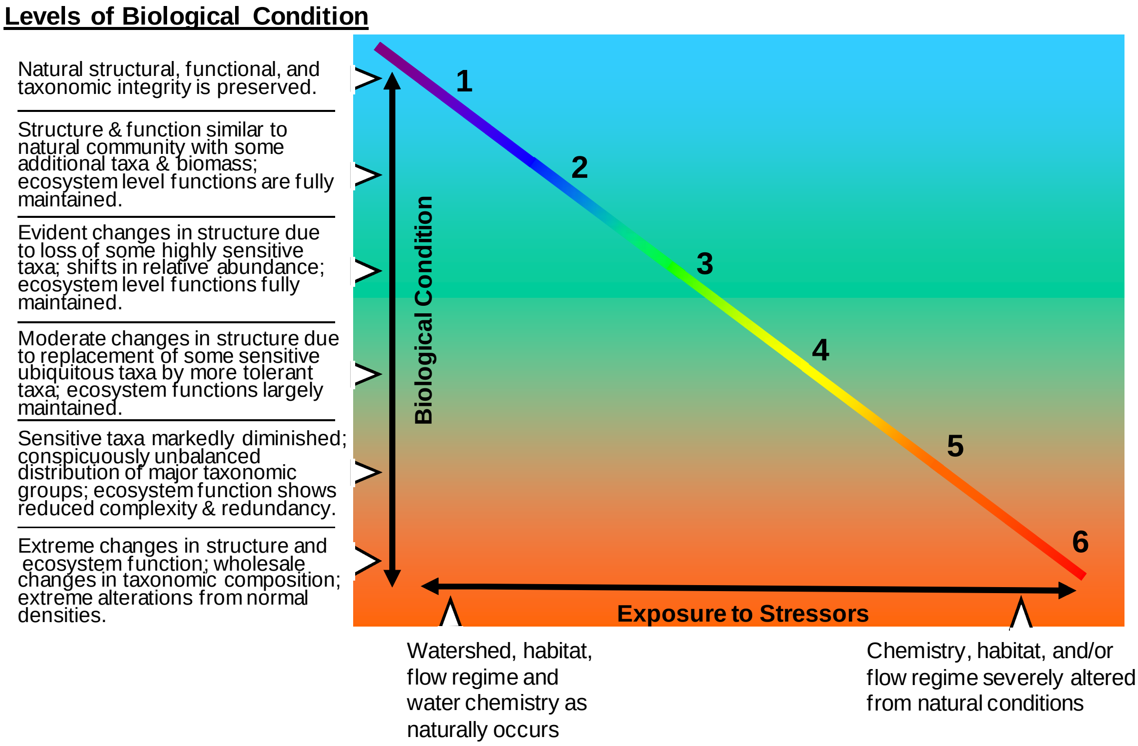

Figure 2. The Biological Condition Gradient (BCG), modified from Davies and Jackson 2006. The BCG was developed to serve as a scientific framework to synthesize expert knowledge with empirical observations and develop testable hypotheses on the response of aquatic biota to increasing levels of stress. It is intended to help support more consistent interpretations of the response of aquatic biota to stressors and to clearly communicate this information to the public, and it is being evaluated and piloted in several regions and states.

In practice, the BCG is used to first identify the critical attributes of an aquatic community and then describe how each attribute changes in response to stress. Practitioners can use the BCG to interpret biological condition along a standardized gradient regardless of assessment method and apply that information to different state or tribal programs. For example, Pennsylvania is using a BCG calibrated to its streams to identify exceptional and high-quality waters based on biological condition (exceptional waters may also be identified with other criteria, say, scenic or recreational value) (US EPA 2011a).

The BCG is divided into six levels of biological condition along the stressor-response curve, ranging from observable biological conditions found at no or low levels of stress (level 1) to those found at high levels of stress (level 6) (Figure 1-2):

> **Level 1.** Native structural, functional, and taxonomic integrity is preserved; ecosystem function is preserved within range of natural variability. Level 1 describes waterbodies that are pristine, or biologically indistinguishable from pristine condition.
>
> **Level 2.** Virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability.

Level 3. Some changes in structure due to loss of some highly sensitive native taxa; shifts in relative abundance of taxa but sensitive–ubiquitous taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system, but may differ quantitatively.

Level 4. Moderate changes in structure due to replacement of sensitive–ubiquitous taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes.

Level 5. Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased buildup or export of unused organic materials.

Level 6. Extreme changes in structure; wholesale changes in taxonomic composition; extreme alterations from normal densities and distributions; organism condition is often poor (e.g. diseased individuals may be prevalent); ecosystem functions are severely altered.

The scientific panels that developed the BCG conceptual model identified 10 attributes of aquatic ecosystems that change in response to increasing levels of stressors along the gradient, from level 1 to 6 (see Table 1). The attributes include several aspects of community structure, organism condition, ecosystem function, spatial and temporal attributes of stream size, and connectivity.

Each attribute provides some information about the biological condition of a waterbody. Combined into a model like the BCG, the attributes can offer a more complete picture about current waterbody conditions and also provide a basis for comparison with naturally expected waterbody conditions. All states and tribes that have applied a BCG used the first seven attributes that describe the composition and structure of biotic community on the basis of the tolerance of species to stressors and, where available, included information on the presence or absence of native and nonnative species and, for fish and amphibians, observations on overall condition (e.g., size, weight, abnormalities, tumors).

The last three BCG attributes of ecosystem function, connectivity, and spatial and temporal extent of detrimental effects can provide valuable information when evaluating the potential for a waterbody to be protected or restored. For example, a manager can choose to target resources and restoration activities to a stream where there is limited spatial extent of stressors or there are adjacent intact wetlands and stream buffers or intact hydrology versus a stream with comparable biological condition but where adjacent wetlands have been recently eliminated, hydrology is being altered, and stressor input is predicted to increase.

Table 1. Biological and other ecological attributes used to characterize the BCG.

Attribute	Description
I. Historically documented, sensitive, long-lived, or regionally endemic taxa	Taxa known to have been supported according to historical, museum, or archeological records, or taxa with restricted distribution (occurring only in a locale as opposed to a region), often due to unique life history requirements (e.g., sturgeon, American eel, pupfish, unionid mussel species).
II. Highly sensitive (typically uncommon) taxa	Taxa that are highly sensitive to pollution or anthropogenic disturbance. Tend to occur in low numbers, and many taxa are specialists for habitats and food type. These are the first to disappear with disturbance or pollution (e.g., most stoneflies, brook trout [in the east], brook lamprey).
III. Intermediate sensitive and common taxa	Common taxa that are ubiquitous and abundant in relatively undisturbed conditions but are sensitive to anthropogenic disturbance/pollution. They have a broader range of tolerance than Attribute II taxa and can be found at reduced density and richness in moderately disturbed sites (e.g., many mayflies, many darter fish species).
IV. Taxa of intermediate tolerance	Ubiquitous and common taxa that can be found under almost any conditions, from undisturbed to highly stressed sites. They are broadly tolerant but often decline under extreme conditions (e.g., filter-feeding caddisflies, many midges, many minnow species).
V. Highly tolerant taxa	Taxa that typically are uncommon and of low abundance in undisturbed conditions but that increase in abundance in disturbed sites. Opportunistic species able to exploit resources in disturbed sites. These are the last survivors (e.g., tubificid worms, black bullhead).
VI. Nonnative or intentionally introduced species	Any species not native to the ecosystem (e.g., Asiatic clam, zebra mussel, carp, European brown trout). Additionally, there are many fish native to one part of North America that have been introduced elsewhere.
VII. Organism condition	Anomalies of the organisms; indicators of individual health (e.g., deformities, lesions, tumors).
VIII. Ecosystem function	Processes performed by ecosystems, including primary and secondary production; respiration; nutrient cycling; decomposition; their proportion/dominance; and what components of the system carry the dominant functions. For example, shift of lakes and estuaries to phytoplankton production and microbial decomposition under disturbance and eutrophication.
IX. Spatial and temporal extent of detrimental effects	The spatial and temporal extent of cumulative adverse effects of stressors; for example, groundwater pumping in Kansas resulting in change in fish composition from fluvial dependent to sunfish.
X. Ecosystem connectivity	Access or linkage (in space/time) to materials, locations, and conditions required for maintenance of interacting populations of aquatic life; the opposite of fragmentation. For example, levees restrict connections between flowing water and floodplain nutrient sinks (disrupt function); dams impede fish migration, spawning. Extensive burial of headwater streams leads to cumulative downstream impacts to biota through energy input disruption, habitat modification, and loss of refugia and dispersing colonists.

Source: Modified from Davies and Jackson 2006.

The BCG model provides a framework to help water quality managers do the following:

Decide what environmental conditions are desired (goal-setting)—The BCG can provide a framework for organizing data and information and for setting achievable goals for waterbodies relative to “natural” conditions, e.g., condition comparable or close to undisturbed or minimally disturbed condition.

Interpret the environmental conditions that exist (monitoring and assessment)— managers can get a more accurate picture of current waterbody conditions.

Plan for how to achieve the desired conditions and measure effectiveness of restoration—The BCG framework offers water program managers a way to help evaluate the effects of stressors on a waterbody, select management measures by which to alleviate those stresses, and measure the effectiveness of management actions.

Communicate with stakeholders—When biological and stress information is presented in this framework, it is easier for the public to understand the status of the aquatic resources relative to what high-quality places exist and what might have been lost.

Specifically, biological assessment information has been used by federal, state, tribal and local governments to:

- **Define goals for a waterbody—**Information on the composition of a naturally occurring aquatic community can provide a description of the expected biological condition for other similar waterbodies and a benchmark against which to measure the biological integrity of surface waters. Many states and tribes have used such information to more precisely define their designated aquatic life uses, develop biological criteria, and measure the effectiveness of controls and management actions to achieve those uses.

- **Report status and trends—**Depending on level of effort and detail, biological assessments can provide information on the status of the condition of the expected aquatic biota in a waterbody and, over time with continued monitoring, provide information on long-term trends.

- **Identify high-quality waters and watersheds—**Biological assessments can be used to identify high-quality waters and watersheds and support implementation of antidegradation policies.

- **Document biological response to stressors—**Biological assessments can provide information to help develop biological response signatures (e.g., a measurable, repeatable response of specific species to a stressor or category of stressors). Examples include sensitivity of mayfly species (pollution-sensitive aquatic insects) to metal toxicity or temperature-specific preferences of fish species. Such information can provide an additional line of evidence to support stressor identification and causal analysis (US EPA 2000), as well as to inform numeric criteria development (US EPA 2011b).

1.3 Calibrating the Conceptual BCG Model to Local Conditions

The BCG can serve as a starting point for defining the response of aquatic biota to increasing levels of stress in a specific region. The model can be applied to any region or waterbody by calibrating it to local conditions using specific expertise and local data. To date, most states and tribes are calibrating the BCG using the first seven attributes that characterize the biotic community primarily on the basis of tolerance to stressors, presence/absence of native and nonnative species, and organism condition.

A multistep process is followed to calibrate a BCG to local conditions (Figure 3); to describe the native aquatic assemblages under natural conditions; to identify the predominant regional stressors; and to describe the BCG, including the theoretical foundation and observed assemblage response to stressors. Calibration begins with the assembly and analysis of biological monitoring data. Next, a calibration workshop is held in which experts familiar with local conditions use the data to define the ecological attributes and set narrative statements; for example, narrative decision rules for assigning sites to a BCG level on the basis of the biological information collected at sites. Documentation of expert opinion in assigning sites to BCG levels is a critical part of the process. A decision model can then be developed that encompasses those rules and is tested with independent data sets. A decision model based on the tested decision rules is a transparent, formal, and testable method for documenting and validating expert knowledge. A quantitative data analysis program can then be developed using those rules.

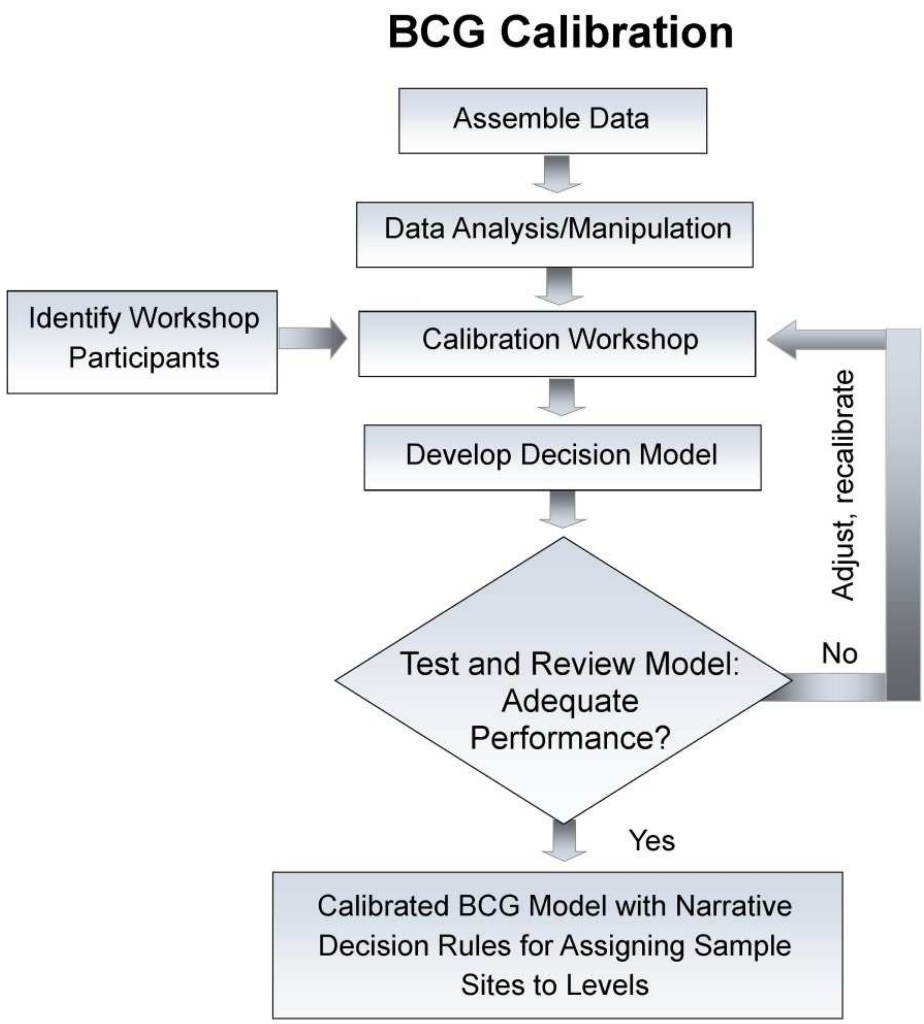

Figure 3. Steps in a BCG calibration.

2 METHODS AND DATA

2.1 Calibrating of the Conceptual BCG Model to Local Conditions

2.1.1 Assign Sites to Levels

The conceptual model of the BCG is intended to be universal (US EPA 2005, Davies and Jackson 2006), but descriptions of communities, species, and their responses to the stressor gradient are specific to the conditions and communities found in the sample region. Before assigning sites to BCG levels, the expert panel begins by describing the biological condition levels that can be discerned within their region. The description of natural conditions requires biological knowledge of the region, a natural classification of the assemblages, and, if available, historical descriptions of the habitats and assemblages.

The panelists examine species composition and abundance data from sites with different levels of cumulative stress, ranging from least stressed to severely stressed. The panel works with data tables showing the species and attributes for each sample. In developing assessments, the panel works "blind", that is, no stressor information is included in the data table. Only non-anthropogenic classification variables are shown (e.g., stream size, sample date). Panel members discuss the species composition and what they expect to see for each level of the BCG (e.g., "I expect to see more stonefly taxa in a BCG level 2 site"), and then assign samples to BCG levels. These site assignments are used to describe changes in the aquatic communities for a range of anthropogenic stress, leading to a complete descriptive model of the BCG for the region.

2.1.2 Quantitative Description

BCG level descriptions in the conceptual model tend to be rather general (e.g., "reduced richness"). To allow for consistent assignments of sites to levels, it is necessary to formalize the expert knowledge by codifying level descriptions into a set of rules (e.g., Droesen 1996). If formalized properly, any person (with data) can follow the rules to obtain the same level assignments as the group of experts. This makes the actual decision criteria transparent to stakeholders.

Rules are logic statements that experts use to make their decisions; for example, "If taxon richness is high, then biological condition is high." Rules on attributes can be combined, for example: "If the number of highly sensitive taxa (Attribute II) is high, and the number of tolerant individuals (Attribute V) is low, then assignment is level 2." In questioning individuals on how decisions are made in assigning sites to levels, people generally do not use inflexible, "crisp" rules, for example, the following rule is unlikely to be adopted:

"Level 2 always has 10 or more Attribute II taxa; 9 Attribute II taxa is always Level 3."

Rather, people use strength of evidence in allowing some deviation from their ideal for any individual attributes, as long as most attributes are in or near the desired range. Clearly, the definitions of "high," "moderate," "low," etc., are fuzzy. These rules preserve the collective professional judgment of the expert group and set the stage for the development of models that reliably assign sites to levels without having to reconvene the same group. In essence, the rules and the models capture the panel's collective decision criteria.

As the panel assigns example sites to BCG levels, the members are polled on the critical information and criteria they use to make their decisions. These form preliminary, narrative rules that explain how panel members make decisions. For example, "For BCG level 2, sensitive taxa must make up half or more of all taxa in a sample." The decision rule for a single level of the BCG does not always rest on a single attribute (e.g., highly sensitive taxa) but may include other attributes as well (intermediate sensitive taxa, tolerant taxa, indicator species), so these are termed "Multiple Attribute Decision Rules." With data from the sites, the rules can be checked and quantified. Quantification of rules allows users to consistently assess sites according to the same rules used by the expert panel, and allows a computer algorithm, or other persons, to obtain the same level assignments as the panel.

Rule development requires discussion and documentation of BCG level assignment decisions and the reasoning behind the decisions. During this discussion, we record:

- Each participant's decision ("vote") for the site
- The critical or most important information for the decision—for example, the number of taxa of a certain attribute, the abundance of an attribute, the presence of indicator taxa, etc.
- Any confounding or conflicting information and how this was resolved for the eventual decision

Following the initial site assignment and rule development, we develop descriptive statistics of the attributes and other biological indicators for each BCG level determined by the panel. These descriptions assist in review of the rules and their iteration for testing and refinement.

Rule development is iterative, and may require 2 or more panel sessions. Following the initial development phase, the draft rules are tested by the panel with new data to ensure that new sites are assessed in the same way. The new test sites are not used in the initial rule development and also should span the range of anthropogenic stress. Any remaining ambiguities and inconsistencies from the first iterations are also resolved.

2.1.3 Decision Criteria Models

Consensus professional judgment used to describe the BCG levels can take into account nonlinear responses, uncommon stressors, masking of responses, and unequal weighting of attributes. This is in contrast to the commonly-used biological indexes, which are typically unweighted sums of attributes (e.g., multimetric indexes; Barbour et al. 1999, Karr and Chu 1999), or a single attribute, such as observed to expected taxa (e.g., Simpson and Norris 2000, Wright 2000). Consensus assessments built from the professional judgment of many experts result in a high degree of confidence in the assessments, but the assessments are labor-intensive (several experts must rate each site). It is also not practical to reconvene the same group of experts for every site that is monitored in the long term. Since experts may be replaced on a panel over time, assessments may in turn "drift" due to individual differences of new panelists. Management and regulation, however, require clear and consistent methods and rules for assessment, which do not change unless deliberately reset.

Use of the BCG in routine monitoring and assessment thus requires a way to automate the consensus expert judgment so that the assessments are consistent. The expert rules are automated in Multiple Attribute Decision Models. These models replicate the decision criteria of the expert panel by assembling the decision rules using logic and set theory, in the same way the experts used the rules. Instead of a statistical prediction of expert judgment, this approach directly and transparently converts the expert consensus to automated sample assessment. The method uses modern mathematical set theory and logic (called "fuzzy set theory") applied to rules developed by the group of experts. Fuzzy set theory is directly applicable to environmental assessment, and has been used extensively in engineering applications worldwide (e.g., Demicco and Klir 2004) and environmental applications have been explored in Europe and Asia (e.g., Castella and Speight 1996, Ibelings et al. 2003).

Mathematical fuzzy set theory allows degrees of membership in sets, and degrees of truth in logic, compared to all-or-nothing in classical set theory and logic. Membership of an object in a set is defined by its membership function, a function that varies between 0 and 1. To illustrate, we compare how classical set theory and fuzzy set theory treat the common classification of sediment, where sand is defined as particles less than or equal to 2.0 mm diameter, and gravel is greater than 2.0 mm (Demicco and Klir 2004). In classical "crisp" set theory, a particle with diameter of 1.999 mm is classified as "sand", and one with 2.001 mm diameter is classified as "gravel." In fuzzy set theory, both particles have nearly equal membership (approximately 0.5) in both classes (Demicco and Klir 2004). Very small measurement error in particle diameter greatly increases the uncertainty of classification in classical set theory, but not in fuzzy set theory (Demicco and Klir 2004). Demicco and Klir (2004) proposed four reasons why fuzzy sets and fuzzy logic enhance scientific methodology:

- Fuzzy set theory has greater capability to deal with "irreducible measurement uncertainty," as in the sand/gravel example above.
- Fuzzy set theory captures vagueness of linguistic terms, such as "many," "large" or "few."
- Fuzzy set theory and logic can be used to manage complexity and computational costs of control and decision systems.
- Fuzzy set theory enhances the ability to model human reasoning and decision-making, which is critically important for defining thresholds and decision levels for environmental management.

Once the quantitative rules for each BCG level have been developed, they work as a logical cascade from BCG level 1 to level 6. A sample is first tested against the level 1 rules; if the combined rule fails, then the level fails, and the assessment moves down to level 2, and so on (Figure 4). All required rules must be true for a site to be assigned to a level. The output of the inference model may include membership of a sample in a single level only, ties between levels, and varying memberships among two or more levels. The level with the highest membership value is taken as the nominal level.

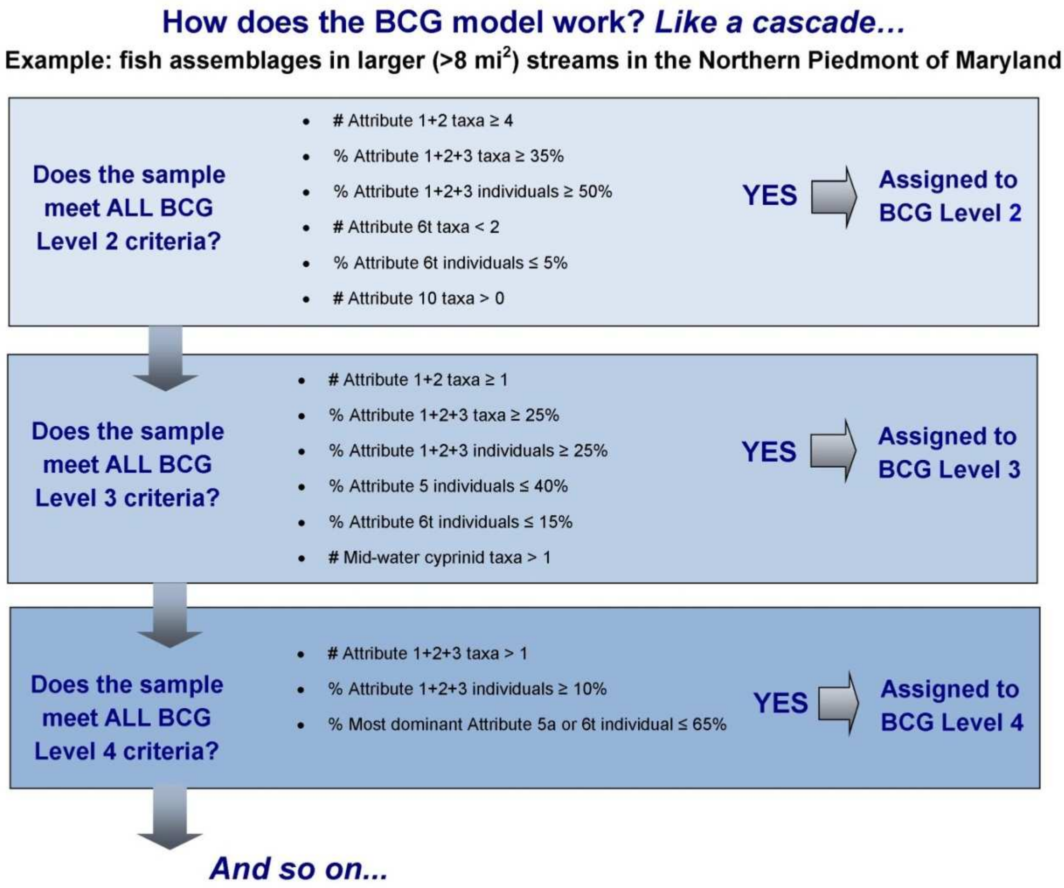

Figure 4. Example flow chart depicting how rules work as a logical cascade in the BCG model. This example is for fish assemblages in larger (>8 mi^2) streams in the Northern Piedmont ecoregion of Maryland (the flow chart starts with BCG level 2 because panelists did not assign any samples in this region to BCG level 1).

2.2 Biological Data

Biological data for three assemblages (fish, macroinvertebrates and salamanders) were obtained from MO DEP and MDDNR's MBSS program. Sampling sites were located in the Northern Piedmont ecoregion (Woods et al. 1999). The fish dataset consisted of 777 samples (62 MO DEP samples and 715 MBSS samples) from 629 unique sites, while the macroinvertebrate dataset had 829 samples (73 MO DEP samples and 756 MBSS samples). Sampling dates for the MBSS data ranged from 1999-2010, while the MO DEP data were collected from 1997 to 2013.

MO DEP and MBSS use similar biological sampling methods. Fish sampling is conducted with a backpack electrofishing unit. Two electrofishing passes are conducted within a 75-meter reach, with channel block nets placed securely at both ends of the reach. All available habitat types are sampled, and all fish are netted and removed during each pass. Fishes greater than 30 mm in length are identified to species and enumerated. Index periods differ slightly, with MBSS fish sampling taking place from June 1 to September 30, and MO DEP sampling going from June 1 to mid-October (Stranko et al. 2014, MO DEP 2014a).

Macroinvertebrate samples are collected from multiple habitats and composited. The habitats are sampled in proportion to their occurrence within the 75-meter reach. All potentially productive habitats are represented in the sample, in the following order of preference: riffles, root wads, root mats/woody debris/snag, leaf packs, submerged aquatic vegetation/associated habitat, undercut banks; less preferred are gravel, broken peat, clay lumps, detrital/sand areas in runs; moving water is preferred over still water. Approximately 20 kicks/jabs/sweeps/rubs are taken from the habitats, with a total sampling area of approximately 20 ft^2. Samples are collected with D-frame nets. Mesh size differs slightly across the two programs (MBSS uses 450-µm and MoCo uses 500-µm). The MBSS index period runs from March 1 to April 30, while MO DEP samples from March 15 to April 30. Both MBSS and MO DEP randomly subsample between 100 and 150 organisms. Most of the identifications are done to genus-level, unless the specimen is damaged or the specimen is an early instar, such that positive identification to genus is not possible (Stranko et al. 2014, MO DEP no date). Oligochaetes are identified to the family-level and Chironomidae are identified to the subfamily or tribe-level, with the following exceptions: 1) prior to 2000, Chironomidae were identified to the family-level; and 2) in recent samples, MBSS started identifying Chironomidae to the genus-level (for purposes of this exercise, the genus-level identifications were collapsed to the tribe-level).

For the salamander surveys, all available cover objects (including cobbles, small boulders, logs, or other objects) are searched within designated areas. The MBSS salamander data that were used for this project were collected from a 25 by 1-meter transect along the wetted edge of one side of the stream (MDDNR 2007). MO DEP collects salamander data from the 75-m stream reach plus the riparian areas on the left and right sides of the stream, with crews searching each area for 10 minutes (MO DEP 2014b). The salamanders are identified to species and enumerated. Incidental encounters (observations outside the focused search effort) are also recorded (MDDNR 2007, MO DEP 2014b).

2.3 Classification

Experience has shown that a robust biological classification is necessary to calibrate the BCG, because the natural biological class indicates the species expected to be found in undisturbed, high-quality sites. As an example, low-gradient prairie or wetland-influenced streams typically contain species that are adapted to slow-moving water and often to hypoxic conditions. These same species found in a high-gradient, forested streams could indicate habitat degradation and organic enrichment.

This project focused on one EPA Level 3 ecoregion (Omernik 1987), the Northern Piedmont. The Northern Piedmont covers parts of New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia, and Virginia, running from southwest to northeast. It is a transitional area, located between topographically flatter coastal areas to the east and more mountainous regions to the west and north. Landforms include low, rounded hills, irregular plains, and open valleys (Woods et al. 1999).

For this project, only sites in the Northern Piedmont region of Maryland were assessed. One BCG model was calibrated for all of the macroinvertebrate samples. Fish and salamander samples were divided into 3 broad groups based on drainage area: small (0.5 to 1.4 mi^2), medium (1.5 – 7.9 mi^2) and large (> 8 mi^2). BCG models were calibrated for each of these 3 size classes. Thresholds were selected based on input from the expert panel. Stream size exerts a major influence on the longitudinal shift in fish assemblages (Vannote et al. 1980, Kanno and Vokoun 2008). Streams with drainage areas less than 0.5 mi^2 were assessed but later excluded from the BCG calibration dataset because there are too few species in streams of this size to calibrate a BCG model.

2.4 BCG Calibration Exercise

Calibration of the BCG for a region is a collective exercise among regional biologists to develop consensus assessments of sites, and then to elicit the rules that the biologists use to assess the sites (Davies and Jackson 2006). On March 27, 2013, Montgomery County convened a panel of 17 scientists with expertise in stream ecology, benthic macroinvertebrate (e.g. insects, crayfish, mussels, snails, worms) and fish and salamander community assessments. The experts attending the meeting included scientists from Montgomery County, the MNCPPC, the State of Maryland Department of Natural Resources and the Department of Environment, the University of Maryland, the University of Maryland at Baltimore County, the Interstate Commission Potomac River Basin and US EPA. At this all-day meeting, a narrative BCG model was developed for 1^{st} to 3^{rd} order streams with catchment areas ranging from 0.5 to 5 mi^2 in the Northern Piedmont of Montgomery County, Maryland (Appendix B), and a preliminary model for the Ten Mile Creek (TMC) watershed was developed and tested successfully (Jackson et al. 2013).

On September 24 – 26, 2013, Montgomery County convened a second expert meeting with a larger number of sites for analysis and with an expanded group of experts, including scientists from the states of Virginia, Pennsylvania and Delaware. A more robust and in-depth analysis of the sites was necessary to refine the model developed during the March meeting. The goal was to develop a set of decision criteria rules for assigning sites to the BCG levels for streams in the Northern Piedmont ecoregion of Maryland. As part of this process, panelists first assigned BCG attributes to macroinvertebrate, fish and salamander taxa (Tables 1 & 2, Appendices C and D). Panelists assigned Attribute 6 (non-native) fish taxa to sub-attributes to distinguish sensitive, intermediate and tolerant taxa (Table 2). Table 2 contains a summary of how many macroinvertebrate, fish and salamander taxa were assigned to each attribute group. Examples of Northern Piedmont taxa that were assigned to each attribute group are listed in Tables 3 and 4. Prior to making attribute assignments, panelists reviewed plots showing the capture probabilities of macroinvertebrate and fish taxa versus disturbance gradients to help inform their decisions (Appendices E and F, respectively).

During the September workshop, the panelists examined biological data from individual sites and assigned those samples to levels 1 to 6 of the BCG. The intent was to achieve consensus and to identify rules that experts were using to make their assignments. The data that the experts examined when making BCG level assignments were provided in worksheets. The worksheets contained lists of taxa, taxa abundances, BCG attribute levels assigned to the taxa, BCG attribute metrics and limited site information, such as watershed area, size class (e.g., headwater), and percent forest. Participants were not allowed to view Station IDs or waterbody names when making BCG level assignments, as this might bias their assignments. Sample fish and macroinvertebrate worksheets can be found in Appendix G.

A preliminary set of decision rules were developed based on these calibration worksheets. In the final session of the workshop, panelists were asked to review decisions and notes, and identify the rules they used to make those decisions. These rules were later quantified and automated in an Excel spreadsheet and BCG level assignments were calculated for each sample. The model-assigned BCG level assignments were then compared to the BCG level assignments that had been made by the panelists to evaluate model performance. On November 7, 2013, a follow-up webinar was held to discuss samples that had the greatest differences between the BCG level assignments based on the model versus the panelists. Decision rules were adjusted based on group consensus. Then the panelists worked individually to make BCG level assignments on additional samples to confirm the BCG models. A final webinar was held on April 29, 2014 to discuss the performance of the models on the calibration and confirmation datasets, to reach consensus on samples where the BCG model output did not match exactly with the group consensus, and to finalize the rules.

Table 1. Descriptions of the BCG attributes assigned to taxa for this exercise, plus a summary of how many taxa were assigned to each attribute group. Some of the taxa that were assessed occur in the region but are not present in the project dataset (tallies are broken into 'All' (=all taxa that were assessed) and 'Proj (= only taxa that occur in the project dataset).

BCG Attribute	Description	Fish taxa		Invertebrate taxa		Salamander taxa
		All	Proj	All	Proj	
I	Historically documented, sensitive, long-lived or regionally endemic taxa	5	1	0	0	0
II	Highly sensitive taxa, often occur in low abundance	7	6	58	35	3
III	Intermediate sensitive taxa	10	10	90	68	0
IV	Taxa of intermediate tolerance	13	13	178	105	1
V	Tolerant native taxa	11	11	93	36	0
VI	Non-native taxa	--	--	5	1	0
VIi	Sensitive non-native (e.g., highly-valued recreational taxa like salmonids)	2	2	--	--	--
VIm	Non-native taxa of intermediate tolerance	6	5	--	--	--
VIt	Highly tolerant non-native taxa	7	7	--	--	--
X	Catadromous fish, indicating ecosystem connectivity	3	3	0	--	--
x	No attribute assignment (insufficient information)	15	15	198	46	9
Totals		***79***	***73***	***622***	***291***	***12***

Table 2. Examples of Northern Piedmont fish and salamanders by attribute group.

Ecological Attribute	Example Species
I Endemic, rare	Brook Trout, Bridle Shiner, Chesapeake Log Perch, Maryland Darter, Trout Perch
II Highly Sensitive	Yellow Perch, Northern Hog Sucker, Margined Madtom, Dusky Salamander, Long-Tailed Salamander
III Intermediate Sensitive	Fallfish, Fantail Darter, Potomac Sculpin, Blue Ridge Sculpin
IV Intermediate Tolerant	Channel Catfish, Least Brook Lamprey, Pumpkinseed, Tessellated Darter, Northern Two-Lined Salamander
V Tolerant	American Eel, Mummichog, White Sucker, Sea Lamprey,
VI-i Sensitive Nonnative	Brown Trout, Rainbow Trout
VI-m Intermediate nonnative	Black Crappie, Golden Redhorse, Smallmouth Bass
VI-t Tolerant nonnative	Common Carp, Goldfish, Green Sunfish, Largemouth Bass, Snakehead
x Unassigned	Unidentified fish, hybrids

Table 3. Examples of Northern Piedmont benthic macroinvertebrates by attribute group.

Ecological Attribute	Example Species
I Endemic, rare	None attributed
II Highly Sensitive	Mayflies: *Habrophlebia, Epeorus, Ephemera, Leucrocuta, Habrophlebiodes, Paraleptophlebia*, Stoneflies*: Sweltsa, Talloperla, Eccoptura*, Caddisflies: *Wormaldia, Diplectrona, Rhyacophila, Dolophilodes*, Flies: *Dixa*, Prodiamesinae
III Intermediate Sensitive	Mayflies: *Diphetor, Ephemerella, Ameletus, Serratella,* Stoneflies: *Amphinemura, Acroneuria, Leuctra, Isoperla*, Dragonflies: *Cordulegaster, Lanthus,* Caddisflies: *Neophylax, Rhyacophila, Pycnopsyche, Glossosoma*, Beetles*: Oulimnius, Anchytarsus,* Flies: Diamesinae, *Hexatoma, Prosimulium*
IV Intermediate Tolerant	Mayflies: *Baetis, Stenonema,* Damsel and Dragonflies: *Calopteryx, Boyeria*, Caddisflies: *Hydropsyche, Polycentropus,* Beetles: *Helichus, Optioservus,* Fishflies: *Nigronia*, Other*: Chelifera,* Tanytarsini, *Tipula, Tabanidae, Crangonyx,* Enchytraeidae
V Tolerant	Beetles*:* Hydrophilidae, Dytiscidae, Flies: *Hemerodromia,* most Chironomini and Orthocladiinae, Stratiomyiidae, Other: Isopoda, Physidae, Hirudinae, Tubificidae
V Nonnative	Asian Clam: *Corbicula,* Snails: *Bithnya*
x Unassigned	Ambiguous family-level or order-level identifications, unknown tolerance

3 DECISION RULES AND BCG MODEL FOR MACROINVERTEBRATES

The macroinvertebrate BCG model was calibrated using MO DEP and MBSS samples. During the calibration exercise, panelists made BCG level assignments on 46 samples. In order to confirm the model, panelists made BCG level assignments on 14 additional samples. BCG level assignments for these 60 samples are summarized in Appendix H.

3.1 Site Assignments and BCG Level Descriptions

The group assigned macroinvertebrate samples to 5 BCG levels (BCG levels 2-6) (Table 5). Locations of the assessed sites are shown in Figure 5. There was never a majority opinion for sites at BCG level 1, which is the most pristine condition (Davies and Jackson 2006). Participants agreed that all sites within the Northern Piedmont ecoregion have some degree of disturbance, including legacy effects from agriculture and forestry from 100 to 200 years ago (Jackson et al. 2013), so BCG level 2 samples represent the highest quality waters in this exercise. Of the 60 samples that were assessed, 7 were assigned to BCG level 2 and 4 were assigned to BCG level 6, which represents the most highly stressed condition. The majority of samples were assigned to BCG levels 3 and 4 (Table 5).

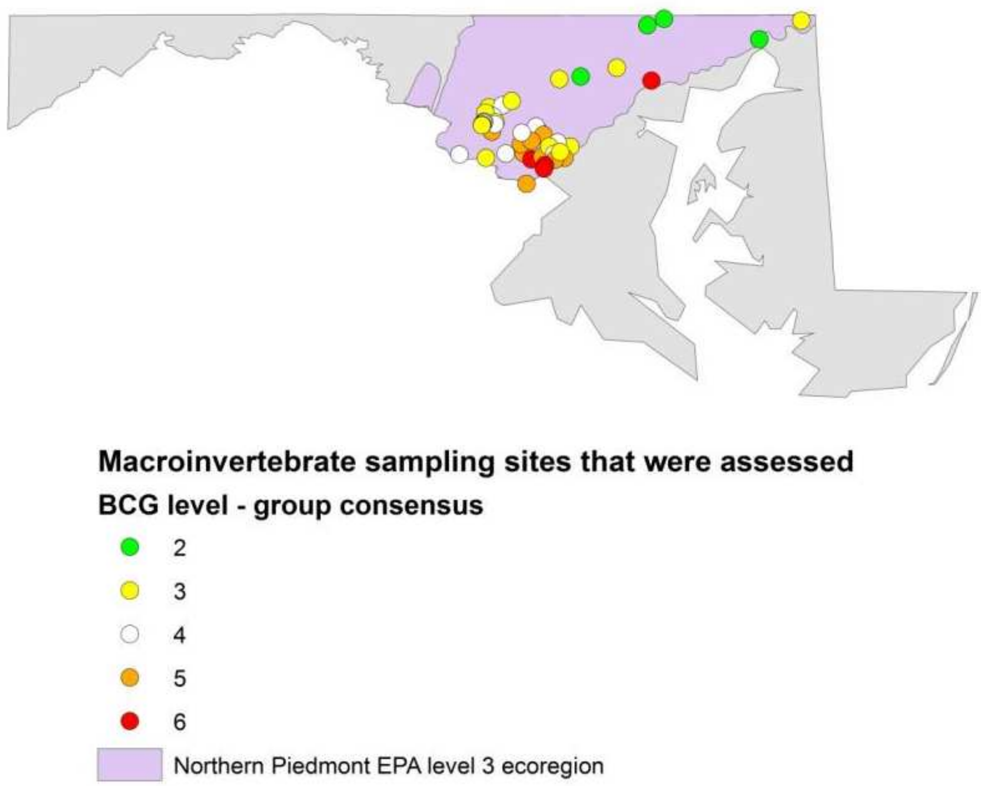

Figure 5. Locations of assessed macroinvertebrate samples, coded by panelist BCG level assignment (group majority choice).

Table 4. Number of calibration and confirmation macroinvertebrate samples that were assessed, organized by BCG level (group consensus).

BCG level	Calibration	Confirmation
1	0	0
2	4	3
3	14	6
4	14	3
5	10	2
6	4	0
Totals	***46***	***14***

3.2 BCG Attribute Metrics

Examinations of taxonomic attributes among the BCG levels determined by the panel showed that several of the attributes are useful in distinguishing levels, and indeed, were used by the panel's biologists for decision criteria. The most important considerations were number of total taxa and percent individual and percent taxa metrics for sensitive (Attribute II, III) and tolerant (Attribute V) organisms. The Attribute II percent taxa metric is particularly effective at discriminating between BCG levels 2 and 3 (Figure 6). The Attribute II+III and Attribute V metrics show relatively monotonic patterns, with Attribute V metrics increasing and Attribute II+III metrics decreasing as the assigned BCG level goes from 2 to 6 (Figure 6). The Attribute II+III taxa metrics discriminate well across all levels, while the tolerant taxa metrics discriminate particularly well between BCG levels 4, 5 and 6. BCG level 5 is discriminated from other BCG levels by the dominance of Attribute V individuals and the loss or very limited presence of Attribute II+III taxa (Figure 6). Box plots for all metrics that were considered in this exercise can be found in Appendix I.

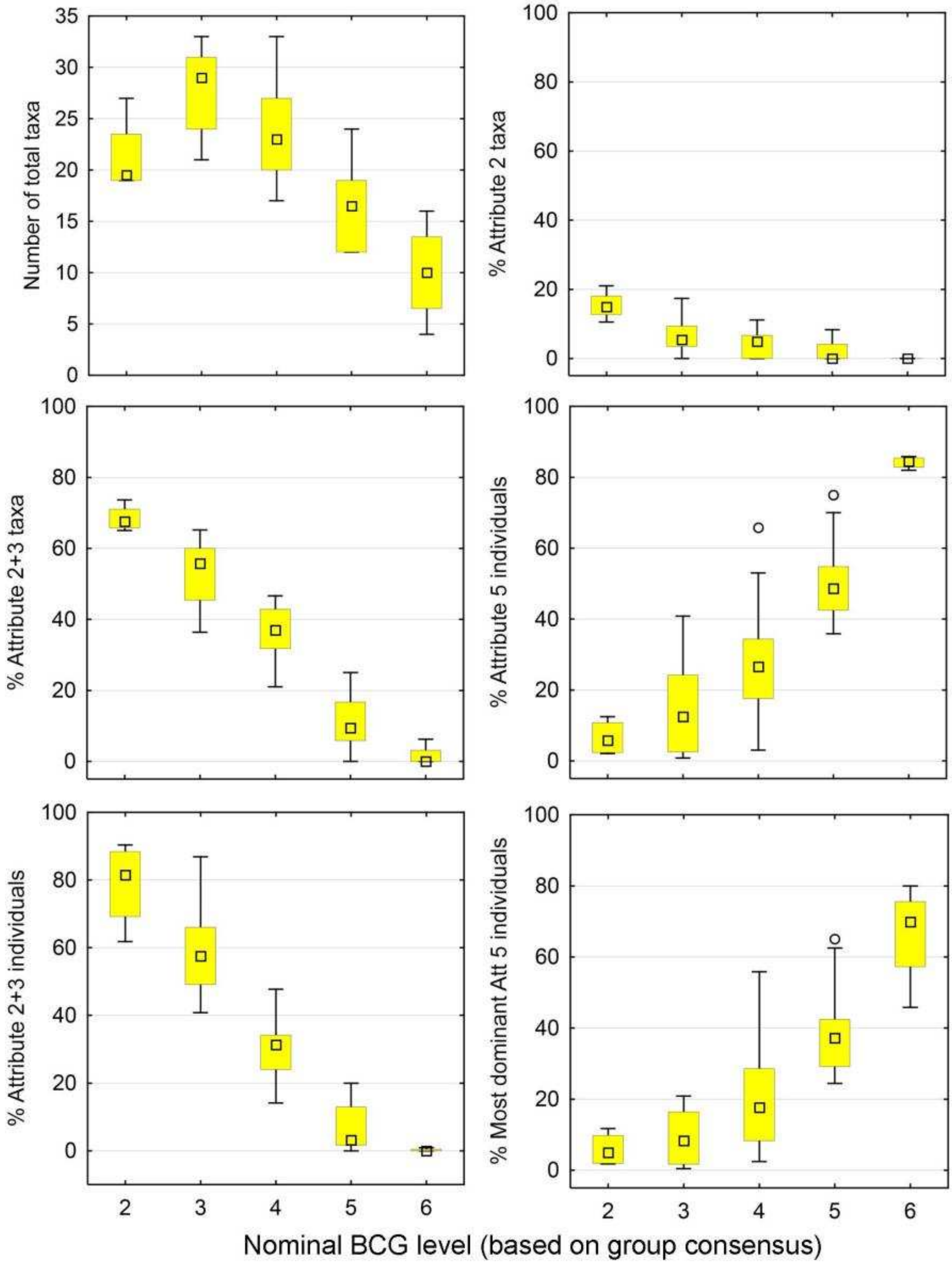

Figure 6. Box plots of sensitive (Attribute II+III) and tolerant (Attribute V) percent taxa and percent individual metrics for macroinvertebrate calibration samples, grouped by nominal BCG level (group majority choice). Sample sizes for each BCG level are summarized in Table 5.

3.3 BCG Rule Development

The rules in Table 6 have been developed for distinguishing BCG levels for streams in the Northern Piedmont ecoregion of Maryland based on the macroinvertebrate assemblage. They were derived from discussions with the panelists on why individual sites were assessed at a certain level. The rules were calibrated and confirmed with the 60 macroinvertebrate samples rated by the group, and were adjusted so that the model would replicate the panel's decisions as closely as possible. Inevitably, there were some decisions where the panel may have used different, unstated rules, or where rules were inconsistently applied.

Table 5. BCG quantitative decision rules for macroinvertebrate assemblages. The numbers in parentheses represent the lower and upper bounds of the fuzzy sets (for more details, see Section 2.1.3).

<table>
<tr><th>BCG Level 2</th><th colspan="2">rule</th></tr>
<tr><td># Total taxa</td><td colspan="2">> 17 (13-22)</td></tr>
<tr><td>% Attribute II taxa</td><td colspan="2">≥ 8% (5-10)</td></tr>
<tr><td>% Attribute II+III taxa</td><td colspan="2">≥ 50% (45-55)</td></tr>
<tr><td>% Attribute II individuals</td><td colspan="2">≥ 3% (2-5)</td></tr>
<tr><td>% Attribute II+III individuals</td><td colspan="2">≥ 60% (55-65)</td></tr>
<tr><td>% Attribute V individuals</td><td colspan="2">≤ 15% (10-20)</td></tr>
<tr><th>BCG Level 3</th><th>alt 1</th><th>alt 2</th></tr>
<tr><td># Total taxa</td><td colspan="2">> 17 (13-22)</td></tr>
<tr><td>% Attribute II+III individuals</td><td colspan="2">≥ 40% (35-45)</td></tr>
<tr><td># Attribute II taxa</td><td>--</td><td>≥ 1 (0-2)</td></tr>
<tr><td>% Attribute II+III taxa</td><td>≥ 25% (20-30)</td><td>≥ 45% (40-50)</td></tr>
<tr><td>% Attribute V individuals</td><td>≤ 40% (35-45)</td><td>≤ 50% (45-55)</td></tr>
<tr><td>% Most dominant Attribute V individual</td><td>≤ 20% (15-25)</td><td>--</td></tr>
<tr><th>BCG Level 4</th><th colspan="2">rule</th></tr>
<tr><td># Total taxa</td><td colspan="2">≥ 15 (10-20)</td></tr>
<tr><td>% Attribute II+III taxa</td><td colspan="2">≥ 20% (15-25)</td></tr>
<tr><td>% Attribute II+III individuals</td><td colspan="2">≥ 10% (5-15)</td></tr>
<tr><td>% Attribute V individuals</td><td colspan="2">≤ 70% (65-75)</td></tr>
<tr><td>% Most dominant Attribute V individual</td><td colspan="2">≤ 60% (55-65)</td></tr>
<tr><th>BCG Level 5</th><th colspan="2">rule</th></tr>
<tr><td># Total taxa</td><td colspan="2">≥ 8 (6-10)</td></tr>
<tr><td>% Attribute V individuals</td><td colspan="2">≤ 85% (80-90)</td></tr>
<tr><td>% Most dominant Attribute V individual</td><td colspan="2">≤ 70% (65-75)</td></tr>
</table>

The basis of the decision rules (Table 6) is a general pattern of decreasing richness of sensitive taxa and increasing relative abundance of tolerant individuals as biological condition degrades (Figure 6). Rules for BCG level 2 have the highest thresholds for sensitive taxa and the lowest thresholds for tolerant organisms. BCG level 3 samples have the same threshold for total taxa richness (17) as BCG level 2 samples and a lower threshold for percent sensitive individuals. There is a set of alternate rules for BCG level 3 that includes combinations of 3 different metrics (Table 6). The transition to BCG level 4 is characterized by a slight decrease in total taxa richness, reduced thresholds for proportions of sensitive taxa and greater presence of tolerant taxa. In BCG level 5 samples, there is a sharp reduction in total taxa richness and a greater abundance of tolerant taxa (Table 6). The requirement for sensitive taxa is dropped for BCG level 5 because sensitive taxa disappear with increasing biological degradation. Samples that fail to meet minimum BCG level 5 requirements are assigned to BCG level 6.

3.4 Model Performance

To evaluate the performance of the 46-sample calibration dataset and the 14-sample confirmation dataset, we assessed the number of samples where the BCG decision model's nominal level exactly matched the panel's majority choice ("exact match") and the number of samples where the model predicted a BCG level that differed from the majority expert opinion ("anomalous" samples). Then, for the anomalous samples, we examined how big the differences were between the BCG level assignments, and also whether there was a bias (e.g., did the BCG model consistently rate samples better or worse than the panelists).

Two types of ties were taken into account: 1) BCG model ties, where there is nearly equal membership in 2 BCG levels (e.g., membership of 0.5 in BCG level 2 and membership of 0.5 in BCG level 3); and 2) panelist ties, where the difference between counts of panelist primary and secondary calls is less than or equal to 1 (e.g., 4-4, or 5-4 decisions). If the BCG model assigned a tie, and that tie did not match with the panelist consensus, we considered this to be a difference of half a BCG level (e.g., if the BCG model assignment was a BCG level 2/3 tie and panelist consensus was a BCG level 2, the model was considered to be 'off 'by a half BCG level; or more specifically, the model rating was ½ BCG level worse than the panelists' consensus). The BCG model was also considered to differ by a half level if the panelists assigned a tie and the BCG model did not.

Results show that the Northern Piedmont BCG model for macroinvertebrates performs well. It is within a half BCG level or better on 95.7% of the calibration samples and 92.9% of the confirmation samples (Table 7). There are 2 anomalous samples in the calibration dataset. For both, the group consensus was BCG level 3 and the model assigned them to BCG level 2 (or '1 better'). With the one anomalous sample in the confirmation dataset, the model assigned the sample to a BCG level that was 1 worse than the group consensus. When half levels are considered, the BCG model differs by a half level on 3 samples, and with all 3, the BCG model rates the sample a half level worse than the panelists (Table 7).

Closer examination of the anomalous samples shows that the model is fairly close to agreement with panelists' consensus calls, or that the anomalous samples have unique characteristics that the BCG model may not be not be calibrated to fully capture. For example, one of the samples that differed by 1 BCG level (Samp047, Site BCBC211) was collected late in the index period (April 29, 1999), and Chironomidae were identified to the family versus the subfamily or tribe-level (nearly all samples in the calibration dataset had Chironomidae identified to the subfamily or tribe-level). Based on the panelists' calls, this sample is a 'borderline' BCG level 2/3 sample (meaning that there was a fairly even split between BCG level calls of 2- and 3+). At the time this sample was assessed, Chironomidae was assigned to BCG attribute V. However, during a later round, it was determined that it would be more appropriate to make Chironomidae a BCG attribute IV taxon, since the subfamilies and tribes have an average attribute assignment of IV, and also because Chironomidae were 'noninformative' as a family when panelists were making their assessments. If this sample were reassessed with Chironomidae listed as a BCG attribute IV taxon, it is possible that the majority of panelists may call this a BCG level 2 sample. Regardless, the model output of 2 is close to the panelist consensus of a ‘borderline’ BCG level 2/3 sample.

The group consensus on the second anomalous calibration sample (Samp052, LOCH-120-S-2009) is also close to the BCG model output. The majority of panelists rated this as a high quality BCG level 3 sample (3+), while some gave it a 2-. The model assigned this to BCG level 2. Panelists cited the prevalence of *Prosimulium*, uncertainty about the unidentified Perlodidae and the low numbers of Attribute II taxa (2 of the 3 highly sensitive taxa occurred as single individuals) as reasons for keeping the group consensus at a BCG level 3 instead of a 2.

The anomalous sample in the confirmation dataset (Samp061, Site LSTM111, collection date 3/29/2012) has unique characteristics that the BCG model may not fully capture. Site LSTM111 is extremely small, with a drainage area of 0.16 mi^2, is spring-fed and supports cold water taxa. The majority of panelists assigned this sample to BCG level 3 and the model assigned it to BCG level 4. The sample narrowly missed the BCG level 3 threshold for the % Attribute II+III individuals metric (the model threshold is 40%, and the metric value for this sample was 36%).

Table 6. Model performance for macroinvertebrate calibration and confirmation samples.

Difference (model vs. panel consensus call)	Calibration		Confirmation	
	Number	Percent	Number	Percent
model - 1 better	2	4.3	0	0.0
model - 1/2 better	0	0.0	0	0.0
exact match	43	93.5	11	78.6
model - 1/2 worse	1	2.2	2	14.3
model - 1 worse	0	0.0	1	7.1
Total # Samples	**46**	**100**	**14**	**100**

4 DECISION RULES AND BCG MODELS FOR FISH & SALAMANDERS

The fish/salamander BCG models were calibrated using MO DEP and MBSS samples. Models were calibrated for 3 drainage area-based stream size classes: small (0.5 to 1.4 mi^2), medium (1.5 – 7.9 mi^2) and larger (> 8 mi^2). During the calibration exercise, panelists made BCG level assignments on 52 samples. In order to confirm the model, panelists made BCG level assignments on 13 additional samples. BCG level assignments for these 65 samples are summarized in Appendix J.

4.1 Site Assignments and BCG Level Descriptions

The group assigned fish/salamander samples to 5 BCG levels (BCG levels 2-6). Most of the samples are in the small and medium size classes (Table 8). Locations of the assessed sites are shown in Figure 7. Of the 65 samples that were assessed, 2 were assigned to BCG level 2. Both of these samples are in the small size class. As with the macroinvertebrate samples, the majority of samples were assigned to BCG levels 3 and 4 (Table 8).

Table 7. Number of calibration and confirmation fish samples that were assessed, organized by BCG level (group consensus). Models were calibrated for 3 drainage area-based stream size classes: small (0.5 to 1.4 mi²), medium (1.5 – 7.9 mi²) and larger (> 8 mi²).

BCG level	Calibration			Confirmation		
	Small	Medium	Large	Small	Medium	Large
1	0	0	0	0	0	0
2	2	0	0	0	0	0
3	9	8	5	3	2	1
4	6	11	1	2	2	0
5	4	4	0	0	1	0
6	1	1	0	2	0	0
Totals	***22***	***24***	***6***	***7***	***5***	***1***

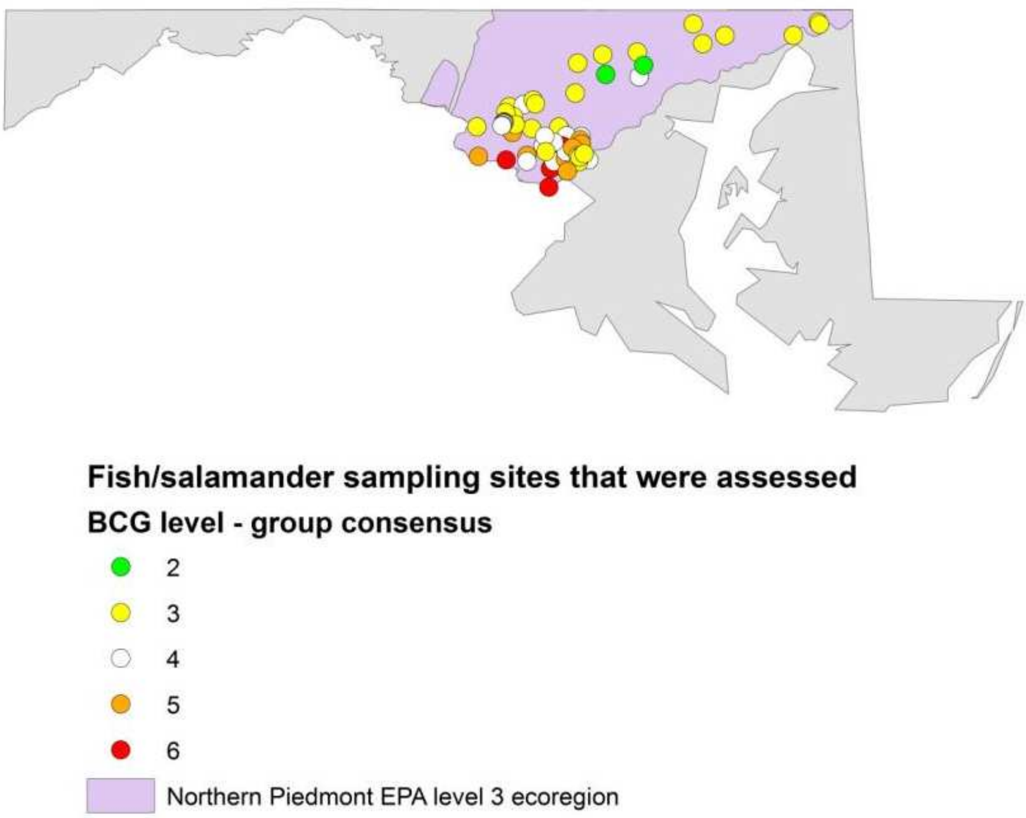

Figure 7. Locations of assessed fish samples, coded by panelist BCG level assignment (group majority choice).

4.2 BCG Attribute Metrics

Examinations of taxonomic attributes among the BCG levels determined by the panel showed that several of the attributes are useful in distinguishing levels, and indeed, were used by the panel's biologists for decision criteria. The most important considerations were percent individual and percent taxa metrics for sensitive (Attribute I, II, III) and tolerant (Attribute V, VIt) organisms. The Attribute I+II+III percent taxa metric discriminates well across all BCG levels (Figure 8). The Attribute II+III and Attribute V metrics generally show monotonic patterns, with Attribute V and VIt metrics increasing and Attribute I+II+II metrics decreasing as the assigned BCG level goes from 2 to 6. The percent Attribute I+II+II individuals metric discriminates particularly well between BCG levels 3, 4 and 5, and the tolerant metrics effectively discriminate BCG level 6 samples.

It should be noted that the percent Attribute V individuals metric was fairly high in the BCG level 2 samples (Figure 8). The two BCG level 2 sites are small streams with brook trout. These were the only samples in the dataset that had brook trout. The percent Attribute V individuals metric was fairly high in these 2 samples because blacknose dace and creek chub, which are both Attribute V taxa, naturally occur in high abundances in small to medium-sized streams that support brook trout. Box plots of additional metrics can be found in Appendix K.

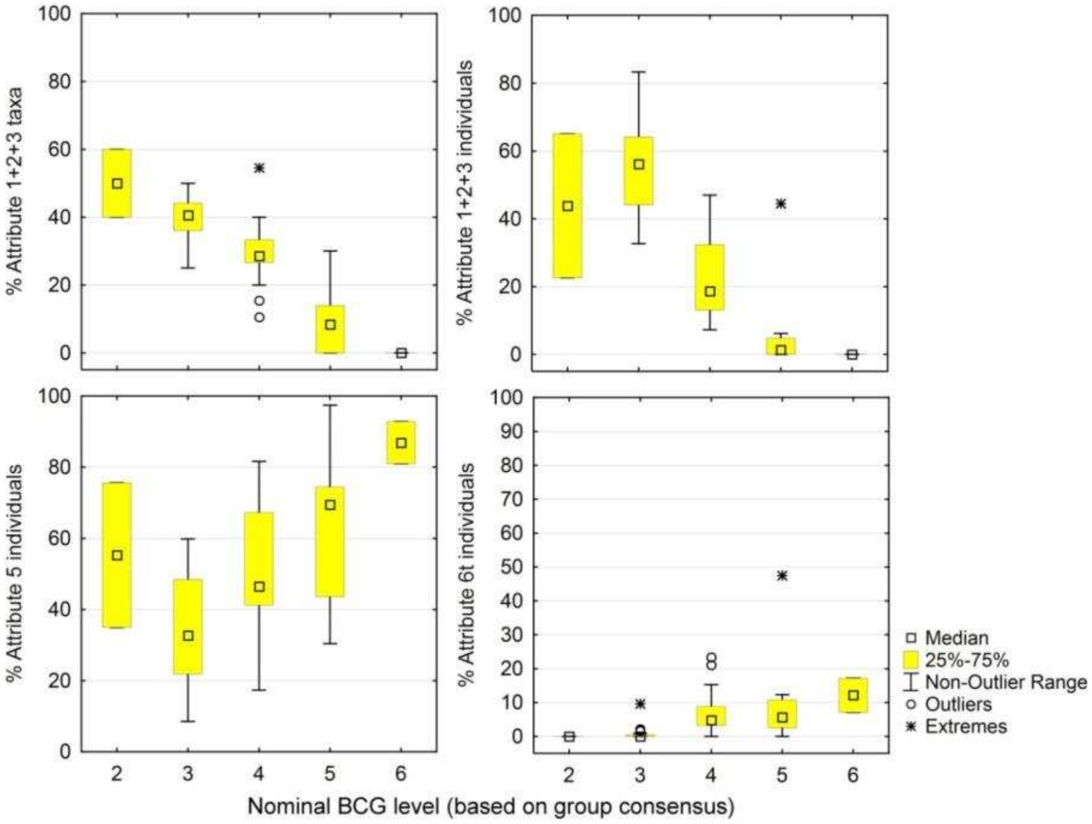

Figure 8. Box plots of sensitive (Attribute II+III) and tolerant (Attribute V and VIt) percent taxa and percent individual metrics for fish calibration samples, grouped by nominal BCG level (group majority choice). Sample sizes for each BCG level are summarized in Table 8.

4.3 BCG Rule Development

The rules in Table 9 have been developed for distinguishing BCG levels for streams based on fish and salamander assemblages. There were some differences in expectations related to stream size (Figure 9), so BCG models were calibrated for 3 watershed area-based size classes: small (0.5 to 1.4 mi^2), medium (1.5 – 7.9 mi^2) and larger (> 8 mi^2). The rules were derived from discussions with the panelists on why individual sites were assessed at a certain level. The rules were calibrated and confirmed with the 65 fish/salamander samples rated by the group, and were adjusted so that the model would replicate the panel's decisions as closely as possible.

The basis of the fish/salamander decision rules (Table 9) is a general pattern of decreasing richness of sensitive taxa and increasing relative abundance of tolerant individuals as biological condition degrades (Figure 8). Sensitive, regionally endemic (Attribute I) taxa must be present in small and medium-sized BCG level 2 streams[1] and catadromous fish (Attribute X) must occur in medium and larger-sized streams. In addition, in larger BCG level 2 streams, highly sensitive (Attribute I, II) fish taxa must be present, and either sensitive salamander taxa (if surveyed) or sensitive or highly sensitive fish taxa must be present in small and medium-sized BCG level 2 streams (Table 9).

Rules for BCG level 3 are similar to level 2, except thresholds for the sensitive and tolerant taxa metrics are less stringent, such that fewer sensitive taxa are required and higher proportions of tolerant taxa are allowed. Mid-water cyprinid taxa (*Notropis*, *Luxilus*, *Clinostomus* and *Cyprinella*, minus swallowtail shiners) must be present in all BCG level 3 samples (Table 9). Some of the BCG level 3 rules differ across size classes. For example, there are two rules that apply only to larger streams. One requires the presence of highly sensitive fish taxa and the other limits the occurrence of tolerant (Attribute V) individuals (Table 9).

In BCG level 4 samples, sensitive fish taxa are still required to be present, albeit in reduced numbers since their occurrence drops with increasing biological degradation. Rules for BCG level 4 also limit how much of the assemblage can be comprised of the most dominant extra tolerant (Attribute Va or VIt) taxon. The BCG level 5 rules utilize two new metrics - number of total taxa and number of total individuals. All BCG level 5 samples must have at least 4 total taxa and 100 total individuals. In addition, the BCG level 5 rules limit the proportion of tolerant and extra tolerant organisms that can occur in medium and larger-sized streams. Samples that fail to meet minimum BCG level 5 requirements are assigned to BCG level 6.

[1] Brook trout is the only Attribute I taxon that occurred in the calibration dataset, and they were present in 2 samples.

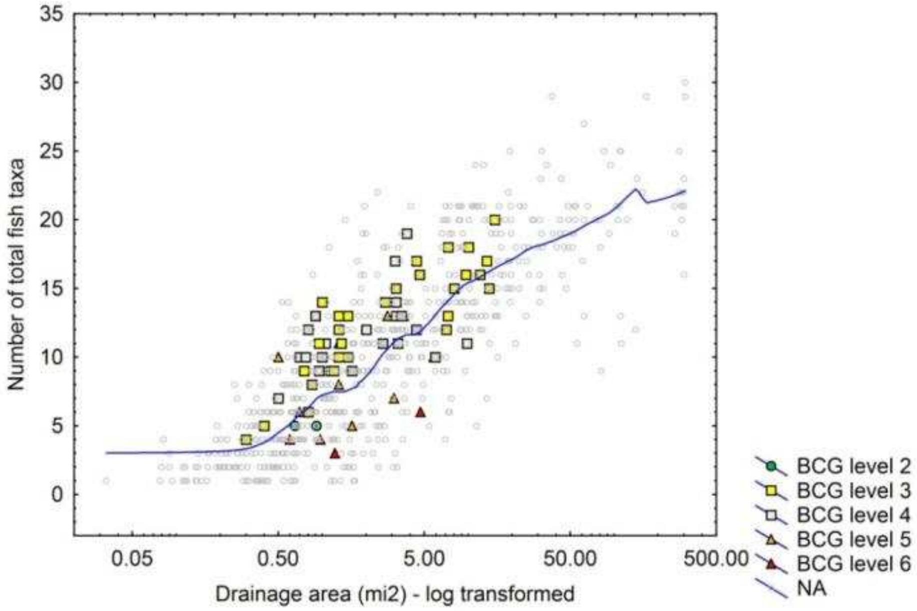

Figure 9. The total taxa richness metric increased with watershed area, consistent with known species-area relationships. This plot is fit with a LOWESS trend line. Samples are coded by nominal BCG level (group majority choice).

Table 8. BCG quantitative decision rules for fish assemblages in small (0.5 to 1.4 mi²), medium (1.5 – 7.9 mi²) and larger streams (> 8 mi²). The numbers in parentheses represent the lower and upper bounds of the fuzzy sets (for more details, see Section 2.1.3). The mid-water cyprinid taxa metric is comprised of *Notropis*, *Luxilus*, *Clinostomus* and *Cyprinella*, minus swallowtail shiners.

BCG Level 2	**Small**		**Medium**		**Large**
	rule	**alt rule**	**rule**	**alt rule**	**rule**
# Attribute I taxa	> 0 (present)		> 0 (present)		--
# Attribute I+II taxa	--		≥ 2 (1-4)		≥ 4 (2-6)
# Attribute I+II+III taxa	> 1 (0-3)	--	--		--
# Sensitive salamander taxa (if surveyed)	--	> 0	--	> 0	--
% Attribute I+II+III taxa	≥ 35% (30-40)		≥ 35% (30-40)		≥ 35% (30-40)
% Attribute I+II+III individuals	--		≥ 50% (45-55)		≥ 50% (45-55)
# Attribute VIt taxa	≤ 2 (1-3)		≤ 2 (1-3)		≤ 2 (1-3)
% Attribute VIt individuals	≤ 5% (3-7)		≤ 5% (3-7)		≤ 5% (3-7)
# Attribute X taxa	--		> 0		> 0
BCG Level 3	**Small**		**Medium**		**Large**
# Attribute I+II taxa	--		--		≥ 1 (0-2)
# Attribute I+II+III taxa	≥ 2 (0-4)		--		--
% Attribute I+II+III taxa	--		≥ 25% (20-30)		≥ 25% (20-30)
% Attribute I+II+III individuals	≥ 25% (20-30)		≥ 25% (20-30)		≥ 25% (20-30)
% Attribute V individuals	--		--		≤ 40% (35-45)
# Attribute VIt taxa	≤ 2 (1-4)		≤ 2 (1-4)		--
% Attribute VIt individuals	≤ 15% (10-20)		≤ 15% (10-20)		≤ 15% (10-20)
# Mid-water cyprinid taxa	> 0		> 1		> 1

Table 9. continued…

BCG Level 4	**Small**	**Medium**	**Large**
# Attribute I+II+III taxa	> 1 (0-3)	> 1 (0-3)	> 1 (0-3)
% Attribute I+II+III individuals	≥ 5% (3-7)	≥ 10% (7-13)	≥ 10% (7-13)
% Most dominant Attribute Va or VIt individual	≤ 65% (60-70)	≤ 65% (60-70)	≤ 65% (60-70)
BCG Level 5	**Small**	**Medium**	**Large**
# Total taxa	> 4 (3-6)	> 4 (3-6)	> 4 (3-6)
# Total individuals	> 100 (90-110)	> 100 (90-110)	> 100 (90-110)
% Attribute V+VIt taxa	--	≤ 65 (60-70)	≤ 65 (60-70)
% Attribute V+VIt individuals	--	≤ 90 (85-95)	≤ 90 (85-95)

4.4 Model Performance

To evaluate the performance of the 52-sample calibration dataset and the 13-sample confirmation dataset, we assessed the number of samples where the BCG decision model's nominal level exactly matched the panel's majority choice and the number of anomalous samples, or samples where the model predicted a BCG level that differed from the majority expert opinion. Then, for the anomalous samples, we examined how big the differences were between the BCG level assignments, and also whether there was a bias (e.g., did the BCG model consistently rate samples better or worse than the panelists). Ties were taken into account as described in Section 3.4.

The Northern Piedmont BCG models for fish and salamanders perform well, matching within a half BCG level or better with the panelist consensus assignments on 100% of the calibration samples and 92.3% of the confirmation samples (Table 10). In the confirmation dataset, there is 1 sample that differs by 1 BCG level (Samp064, Station LSLS206, collection year 2013, small size class). The majority of panelists assigned this sample to BCG level 3 and the model assigned it to BCG level 4 ('1 worse'). The model assigned this sample to BCG level 4 because it fails the BCG level 3 rule that requires the presence of mid-water cyprinid taxa (*Notropis*, *Luxilus*, *Clinostomus* and *Cyprinella*, minus swallowtail shiners). This is the only BCG level 3 sample to fail this rule, so we did not feel that a rule change was warranted. In the calibration dataset, the BCG model differs by a half level on 2 samples. With one, the BCG model rates the sample a half level worse than the panelists, and with the other, a half level better (Table 10.)

Table 10. Model performance for fish/salamander calibration and confirmation samples.

Difference (model vs. panel consensus call)	**Calibration**		**Confirmation**	
	Number	**Percent**	**Number**	**Percent**
model - 1 better	0	0.0 %	0	0.0 %
model - 1/2 better	1	1.9 %	0	0.0 %
exact match	50	96.2 %	12	92.3 %
model - 1/2 worse	1	1.9 %	0	0.0 %
model - 1 worse	0	0.0 %	1	7.7 %
Total # Samples	**52**	**100 %**	**13**	**100 %**

5 DESCRIPTION OF ASSEMBLAGES IN EACH BCG LEVEL

When panelists assess samples, they often associate particular taxa (and abundances of these taxa) with certain BCG levels. In Table 11, we provide narrative descriptions of each of the BCG levels that were assessed during this exercise (modified after Jackson et al. 2013), as well as lists of fish, salamander and macroinvertebrate taxa that were commonly found in samples from each BCG level. Pictures of some of the important aquatic species that occur in Maryland's Northern Piedmont headwater streams are shown in Figure 10.

Table 11. Description of fish, salamander and macroinvertebrate assemblages in each assessed BCG level. Definitions are modified after Davies and Jackson (2006).

BCG level 1	**Definition:** Natural or native condition - *native structural, functional and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability*
	Narrative from expert panel: There are no BCG level 1 sites within the Piedmont. All sites have some degree of disturbance, including legacy effects from agriculture and forestry from 100 to 200 years ago. Conceptually, BCG level 1 sites would have strictly native taxa for all assemblages evaluated (fish, salamander, benthic macroinvertebrates), some endemic species, and evidence of connectivity in the form of migratory fish.
	Fish: Examples of endemic species that might be present (depending on the size of the stream) include: Bridle Shiner, Brook Trout, Chesapeake Logperch, Maryland Darter, Trout Perch
	Macroinvertebrates: Sensitive-rare, cold water indicator taxa such as the mayfly *Epeorus*, and stoneflies *Sweltsa* and *Talloperla* are expected to be present
BCG level 2	**Definition:** Minimal changes in structure of the biotic community and minimal changes in ecosystem function - *virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability*
	Narrative from expert panel: Overall taxa richness and density is as naturally occurs (watershed size is a consideration). These sites have excellent water quality and support habitat critical for native taxa. They have many highly sensitive taxa and relatively high richness and abundance of intermediate sensitive-ubiquitous taxa. Many of these taxa are characterized by having limited dispersal capabilities or are habitat specialists. If tolerant taxa are present, they occur in low numbers. There is connectivity between the mainstem, associated wetlands and headwater streams.
	Fish: Highly sensitive (Attribute II) and intermediate sensitive (Attribute III) taxa such as Yellow Perch, Northern Hogsucker, Margined Madtom, Fallfish and Fantail Darter are present, as are native top predators (e.g., Brook Trout). Migratory fish and amphibians (e.g., eel, lamprey, salamanders) are present or known to access the site. Long-Tailed and Dusky Salamanders are also good indicators, given a complimentary fish community. Non-native taxa such as Brown Trout or Rainbow Trout, are absent or, if they occur, their presence does not displace native trout or alter structure and function.
	Macroinvertebrates: Highly sensitive taxa are present - especially coldwater indicator mayflies, stoneflies, and caddisflies (e.g, *Epeorus, Paraleptophlebia, Sweltsa, Tallaperla* and *Wormaldia*) - and occur in higher abundances than in BCG level 3 samples.

Table 11 continued…

BCG level 3	**Definition:** Evident changes in structure of the biotic community and minimal changes in ecosystem function - *Some changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa but intermediate sensitive taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system*
	Narrative from expert panel: Generally considered to be in good condition. Similar to BCG level 2 assemblage except the proportion of total richness represented by rare, specialist and vulnerable taxa is reduced. Intermediate sensitive-ubiquitous taxa have relatively high richness and abundance. Taxa with intermediate tolerance may increase but generally comprise less than half total richness and abundance. Tolerant taxa are somewhat more common but still have low abundance. Taxa with slightly broader temperature or sediment tolerance may be favored.
	Fish: Intermediate sensitive (Attribute III) taxa such as Fallfish and Fantail Darter are common or abundant. Taxa of intermediate tolerance (Attribute IV) such as Channel Catfish, Least Brook Lamprey, Pumpkinseed and Tessellated Darter are present in greater numbers than in BCG level 2 samples. Some tolerant (Attribute V) taxa such as Mummichog and White Suckers may be present, but highly tolerant taxa are absent. Pioneering speices such as Blacknose Dace, Creek Chubs and White Suckers may be naturally common in smaller streams. Migratory species such as American Eel may be absent. Two-lined Salamanders may occur.
	Macroinvertebrates: Similar to BCG level 2 assemblage except sensitive taxa (e.g, *Sweltsa, Tallaperla* and *Wormaldia*) occur in lower numbers. Level 3 indicator taxa include the caddisfly *Diplectrona*, the mayfly *Ephemerella* and the stonefly *Amphinemura*.
BCG level 4	**Definition:** Moderate changes in structure of the biotic community and minimal changes in ecosystem function - *Moderate changes in structure due to replacement of some intermediate sensitive taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes*
	Narrative from expert panel: Sensitive species and individuals are still present but in reduced numbers (e.g., approximately 10 – 30% of the community rather than 50% found in level 3 streams). The persistence of some sensitive species indicates that the original ecosystem function is still maintained albeit at a reduced level. Densities and richness of intermediate tolerance taxa have increased compared to BCG level 3 samples.
	Fish: 2 or 3 sensitive taxa may be present but occur in very low numbers (e.g., Blue Ridge Sculpin, Fantail Darter, Potomac Sculpin, Fallfish, Rosy-Side Dace, River Chub). Taxa of intermediate tolerance (Attribute IV) such as Tesselated Darter, Least Brook Lamprey, Longnose Dace are common, as well as tolerant taxa like Yellow Bullhead, Red-Breast Sunfish and Bluntnose Minnow. Level 4 streams may harbor 2 to 3 salamander species (Dusky, Red, and Two-lined).
	Macroinvertebrates: Sensitive taxa (including EPT taxa) are present but occur in low numbers. Taxa such as *Diplectrona* and *Dolophilodes* may occur, but other key taxa such as *Ephemerella* and *Neophylax* are absent. Taxa of intermediate tolerance (e.g., *Baetis, Stenonema, Caenis, Chimarra, Cheumatopsyche, Hydropsyche*) occur in greater numbers. Tolerant taxa such as Chironomini and Orthocladiinae are present but do not exhibit excessive dominance.

Table 11 continued…

BCG level 5	**Definition:** Major changes in structure of the biotic community and moderate changes in ecosystem function - *Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build-up or export of unused materials*
	Narrative from expert panel: Overall abundance of all taxa reduced. Sensitive species may be present but their functional role is negligible within the system. Those sensitive taxa remaining are highly ubiquitous within the region and have very good dispersal capabilities. The most abundant organisms are typically tolerant or have intermediate tolerance, and there may be relatively high diversity within the tolerant organisms. Most representatives are opportunistic or pollution tolerant species.
	Fish: Facultative species reduced or absent. Tolerant taxa like Yellow Bullhead, Red-Breast Sunfish, and Bluntnose Minnow are common. Blacknose Dace, Creek Chubs and White Suckers may dominate. Two-Lined Salamanders might be the only salamander present.
	Macroinvertebrates: Highly sensitive macroinvertebrate taxa are usually absent and Chironomid midges (mostly tolerant Orthocladiinae and Chironomini) often comprised >50% of the community in level 5 streams.
BCG level 6	**Definition:** Major changes in structure of the biotic community and moderate changes in ecosystem function - *Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build-up or export of unused materials*
	Narrative from expert panel: Heavily degraded from urbanization and/or industrialization. Can range from having no aquatic life at all or harbor a severely depauperate community composed entirely of highly tolerant or tolerant invasive species adapted to hypoxia, extreme sedimentation and temperatures, or other toxic chemical conditions.
	Fish: Fish are low in abundance or absent, represented mainly by Blacknose Dace, Green Sunfish, Bluntnose Minnow or Creek Chub.
	Macroinvertebrates: May be dominated by tolerant non-insects (Physid snails; Planariidae; Oligochaeta; Hirudinea; etc.)

Figure 10. Important aquatic species in Maryland's Piedmont headwater streams. Salamanders (Long-Tailed, Dusky, and Red); fishes (Potomac Sculpin, Rosyside Dace, American Eel); Insects (*Sweltsa*, *Paraleptophlebia*, *Ephemerella*).

6 DISCUSSION

Aquatic biologists from the MO DEP, the MNCPPC, the State of Maryland Department of Natural Resources and the Department of Environment, the University of Maryland, the University of Maryland at Baltimore County, the Interstate Commission Potomac River Basin, US EPA and the states of Virginia, Pennsylvania and Delaware partnered to develop a common assessment system based on the BCG for macroinvertebrate, fish and salamander assemblages in streams in the Northern Piedmont ecoregion of Maryland. This was a collective exercise among regional biologists to develop consensus on assessments of samples. We elicited the rules that the biologists used to assess the samples, and developed a set of quantitative decision criteria rules for assigning samples to BCG levels. The biologists working on the macroinvertebrate samples assessed samples independently from the panelists working on the fish and salamander samples.

The fish and macroinvertebrate BCG models performed well, scoring within a half BCG level or better on at least 95% of the calibration samples and on 92% of the confirmation samples. Several sites were assigned to BCG level 2, which, based on participants' input, represent the present-day highest quality waters in this region. Moving ahead, the MO DEP and MDDNR could potentially use the BCG models to supplement the IBI measures that they currently use to assess stream health. As new data are collected, BCG model outputs can be generated using the electronic worksheets that accompany this report. If the BCG models are utilized, users should consider the limitations of the models. Results from the fish/salamander model should be interpreted with caution if it is applied to streams with drainage areas of 0.5 square miles or less. The macroinvertebrate BCG model outputs should be interpreted with caution and checked using professional assessment if: 1) samples are collected early or late in the index period; 2) if levels of taxonomy are inconsistent with those used in the calibration dataset (e.g., if Chironomidae are not identified to the subfamily or tribe-level); and 3) if there are more than 120 total individuals in the sample.[2]

If the BCG models are used to supplement IBI measures, the BCG, as developed conceptually in Davies and Jackson (2006), addresses several limitations of existing biotic indexes. Advantages of the BCG include:

- The BCG is based on ecological considerations with wide expert agreement, rather than on empirical analysis of a particular data set. The resulting index is calibrated using a data set, but the result is intended to be more general than a regression analysis of the data set.

- The BCG uses attributes (Attributes I to VI) that are intended to apply in all regions. Specifics of the attributes (taxon membership, attribute levels indicating good, fair, poor, etc.) do vary across regions and stream types, but the attributes themselves and their importance are consistent.

- The BCG requires descriptions of the classes or levels, from pristine to degraded. While requiring extra work, this ensures that future information and discoveries can be related back to the baseline level descriptions. The general descriptions of the range of the Levels from 1 to 6 are based on existing sound conceptual knowledge. With the description of a baseline of undisturbed, pristine conditions (admittedly imperfect and sometimes incomplete), the BCG is intended to be independent of shifting baselines and relativistic assessments based on the “best that is left”. Descriptions of levels will be enhanced with new data and information.

The BCG developed by the experts here may be more robust than current indexes because it allows, in some cases, for nonlinear responses. The BCG is not conceptually tied to “best available” sites as a reference condition. Although best available sites are used as a practical ground truth, it is recognized at the outset that these sites are typically less than pristine, and may be a lower level (e.g., 2, 3, 4). The levels of the BCG are biologically recognizable stages in the condition of stream waterbodies. As such, they can form a biological basis for criteria and regulation of a state’s waterbodies. Thresholds of narrative biocriteria in some states may be relatively low (e.g., level 4-level 5), and fail to protect outstanding condition waters (levels 1 and 2), or even good condition waters (level 3). Low protection levels are often the result of low levels of rigor in monitoring and assessment (US EPA 2013). Thus, biocriteria set at a lower BCG level will allow incremental degradation of waterbodies to the regulatory level.

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[2] At 4 sites, panelists assessed samples that had been sub-sampled to 120 organisms and samples that had not been sub-sampled (and contained anywhere from 150 to 239 total individuals). We found there to be good correspondence between the BCG scores in both sets of samples. While we expect results between sub-sampled and ‘full’ samples to be similar, we encourage further evaluation of this, since the BCG calibration dataset was comprised primarily of samples that had been sub-sampled to 120 total organisms.

The BCG provides a powerful approach for an operational monitoring and assessment program, for communicating resource condition to the public and for management decisions to protect or remediate water resources. It allows practical and operational implementation of multiple aquatic life uses in a state's water quality criteria and standards. Adoption of the BCG as an assessment tool in the context of multiple Aquatic Life Uses (Tiered Uses) yields the technical tools for protecting the state's highest quality waters, as well as developing realistic restoration goals for urban and agricultural waters. States and tribes could use the BCG model to identify biological expectations for tiered aquatic life uses. Several of the stream sites in least-stressed catchments in this report were rated a BCG level 2 by the panel of biologists. The least-stressed catchments may also correspond to Outstanding or Exceptional waters (this would need to be confirmed).

In the future, the Northern Piedmont BCG models could potentially be expanded beyond Maryland to a regional scale. Regional BCG models that accommodate methodological differences have been developed for cold and cool streams in northern ecoregions of the Upper Midwest and for medium to high gradient streams in parts of New England (Stamp and Gerritsen 2009, Gerritsen and Stamp 2012). The New England model is for macroinvertebrates and is cross-calibrated for methods used by biomonitoring programs in Maine, New Hampshire, Vermont and Connecticut, as well as for US EPA National Rivers and Streams Assessment protocols. The Northern Forest models were developed for macroinvertebrate and fish assemblages for Indian Reservations and the states of Michigan, Wisconsin, and Minnesota. If a similar framework were developed for the Northern Piedmont, the Maryland BCG models would serve as a good starting point.

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Appendix A

Selected Case Examples from “A Primer on Using Biological Assessments to Support Water Quality Management, EPA 810-R-11-01”

3.1 Protecting Water Quality Improvements and High Quality Conditions in Maine

Abstract

Maine has used biological, habitat, and other ecological information to designate aquatic life uses that reflect the highest achievable conditions of its waterbodies and has used antidegradation policy to maintain and protect high existing conditions. Maine uses a Biological Condition Gradient to designate levels of protection for its waterbodies (e.g., designated aquatic life uses) and to assign numeric biological criteria to protect those uses. Maine describes the system as a *tiered use classification*. For Maine, tiered aquatic life uses highlight the relationship between biology, water quality, and watershed condition in determining the need for waterbody protection to maintain existing high quality conditions or the potential for water quality improvement to attain water quality standards. Maine's integrated, data-driven approach has resulted in documented improvement in water quality throughout the state, including upgrades of designated uses of more than 1,300 stream miles, from Class C to Class B, and from Class B to Class A or AA waters (Outstanding National Resource Waters).

In 1983 the Maine Department of Environmental Protection (ME DEP) initiated a statewide biological monitoring and assessment program and revised water quality standards (WQS) by 1986 to recognize high levels of water quality condition. Maine established four classes for freshwater rivers and streams (see Table 3-1). All four classes meet or exceed the Clean Water Act (CWA) section 101(a)(2) goal for aquatic life protection. Every waterbody is assigned to one of four tiers by considering its existing biological condition, its highest achievable condition on the basis of biological potential, aquatic habitat, watershed condition, levels of dissolved oxygen, and numbers of bacteria (Table 3-1). Agency biologists developed a linear discriminant model to measure the biological attainment of each class, establish numeric biological criteria, and assign corresponding antidegradation tiers for purposes of statewide planning (see Table 3-1, column 6). Part of Maine's antidegradation policy requires that where any actual measured water quality criterion exceeds that of a higher class, that quality must be maintained and protected [Maine Revised Statutes Title 38, §464.4(F)]. In effect, by having multiple levels of aquatic life use standards in law, Maine has established a means of improving water quality in incremental steps, and of using antidegradation reviews and reclassification upgrades to maintain and protect water quality and aquatic life conditions that exceed existing or designated aquatic life uses.

The following case study offers an example of how Maine has used tiered use classifications and antidegradation policy cooperatively in its water quality management program. In conjunction with habitat and other chemical and physical parameters, Maine assigns waters to designated use classes (AA, A, B, or C; Table 3-1) on the basis of the *potential* for water quality improvement. In the 1980s, monitoring on the Piscataquis River near the towns of Guilford and Sangerville found aquatic life conditions insufficient to meet even the minimum Class C conditions at which the river was classified. The segment of the river in the Guilford-Sangerville area had a history of poor water quality, including recurrent fish kills from poorly treated industrial and municipal wastes. However, the state determined that this segment of the river could attain at least Class C. The state determined that sewage treatment plant and industrial discharges were the only significant source of stressors to the river, with very good quality upstream conditions and good salmonid production elsewhere. Additionally, the river's habitat structure and hydrologic regime were very good.

Table 3-1. Criteria for Maine River and stream classifications and relationship to antidegradation policy.

Class	Dissolved oxygen criteria	Bacteria criteria	Habitat narrative criteria	Aquatic life narrative criteria*** and management limitations/restrictions	Corresponding federal antidegradation policy tiers
AA	As naturally occurs	As naturally occurs	Free-flowing and natural	As naturally occurs**; no direct discharge of pollutants; no dams or other flow obstructions.	3 (Outstanding National Resource Water [ONRW])
A	7 ppm; 75% saturation	As naturally occurs	Natural**	Discharges permitted only if the discharged effluent is of equal to or better quality than the existing quality of the receiving water; before issuing a discharge permit the Department shall require the applicant to objectively demonstrate to the department’s satisfaction that the discharge is necessary and that there are no reasonable alternatives available. Discharges into waters of this class licensed before 1/1/1986 are allowed to continue only until practical alternatives exist.	2 1/2
B	7 ppm; 75% saturation	64/100 mg (g.m.) or 236/100 ml (inst.)*	Unimpaired**	Discharges shall not cause adverse impact to aquatic life** in that the receiving waters shall be of sufficient quality to support all aquatic species indigenous** to the receiving water without detrimental changes to the resident biological community.**	2 to 2 1/2
C	5 ppm; 60% saturation; and 6.5 ppm (monthly avg.) when temperature is </= 24 °C	125/100 mg (g.m.) or 236/100 (inst.)*	Habitat for fish and other aquatic life	Discharges may cause some changes to aquatic life**, provided that the receiving waters shall be of sufficient quality to support all species of fish indigenous** to the receiving waters and maintain the structure** and function** of the resident biological community. **	1 to 2

Source: Maine DEP (modified).
http://www.maine.gov/dep/blwq/docmonitoring/classification/reclass/appa.htm.

Notes:
* g.m. = geometric mean; inst. = instantaneous level.
** Terms are defined by statute (Maine Revised Statutes Title 38, §466).
*** Numeric biological criteria in Maine regulation Chapter 579, Classification Attainment Evaluation Using Biological Criteria for Rivers and Streams.

Four years after issuance of new National Pollutant Discharge Elimination System (NPDES) permits requiring better industrial pretreatment and improved wastewater treatment at the Guilford-Sangerville treatment facility, follow-up monitoring found water quality improvements that exceeded Class C and attained Class B aquatic life conditions. The achievement of higher water quality conditions was preserved through a classification upgrade process (supported by the industry and the two towns). The river was upgraded to Class B and now attains those higher aquatic life use goals. The redesignation process requires the state legislature to enact a statutory change of a waterbody's classification and can take considerable time to complete. However, during the reclassification process the improved water quality conditions existing in the Piscataquis River were protected through implementation of the state's Tier II antidegradation policy. The value secured by maintaining the higher quality condition was demonstrated in 2009 when the Piscataquis River was designated as critical habitat for the restoration of the endangered Atlantic salmon.

The management actions based on documented improvements in the biological condition in this example demonstrate the complementary application of the state's tiered aquatic life use classification and the Tier 2 and 2½ antidegradation policy. Using that approach, water quality upgrades from Class C to B and from B to A or AA have been repeated in many parts of the state, and subsequently maintained and protected. Overall, Maine has redesignated more than 1,300 miles of streams to a higher class on the basis of biological information (e.g., biological improvements due to point source controls, nonpoint source practices, dam operational modifications or removal) and societal values (e.g., water quality and habitat protection for wild trout populations; critical species protection, especially Atlantic salmon habitat and tribal petitions).

3.2 Protection of Antidegradation Tier II Waters in Maryland

Abstract

Maryland is identifying high-quality waters for antidegradation purposes on a waterbody-by-waterbody basis. Maryland has designated Tier II waters on the basis of two indices of biotic integrity—fish and benthic invertebrates—and provides additional protection so that those waters are not degraded. New or increased point source dischargers and local sewer planning activities that have the potential to affect Tier II waters are required to examine alternatives to eliminate or reduce discharges or impacts. The state has developed requirements that must be met for projects that do not implement a no-discharge alternative. To help local planners to determine whether a planned activity has the potential to affect a Tier II water, the state has developed geographic information system shapefiles that identify such waters. Those files are provided to local jurisdictions to improve their knowledge of where Tier II waters occur. Biological assessments, in conjunction with chemical and physical assessments, are then conducted to determine the status of those waters and detect trends in condition.

In its state water quality standards (WQS), Maryland adopted an antidegradation policy for protecting all waters for existing and designated uses. High-quality (Tier II) waters receive additional attention and regulatory protections. Identification of Tier II waters, in this case streams, is based on a waterbody-by-waterbody approach using biological survey data, from which two indices of biotic integrity (IBIs) are developed—one for benthic invertebrates and one for fish. Those with both scores above 4 are designated Tier II waters. The state has identified more than 230 high-quality water segments. To protect downstream high-quality waters, a watershed approach to protection is applied. Tier II waters must be protected so that water quality does not degrade to minimum standards, and that requirement has implications for potential discharges and local planning activities.

Application of Tier II Protection

The Maryland Department of the Environment (MDE) requires that applicants for amendments to county plans (i.e., water and sewer plans) or permits for new or expanding point source discharges evaluate alternatives to eliminate or reduce discharges or impacts [COMAR 26.08.02.04-1(B)]. Applicants for permits must consider whether the receiving waterbody is Tier II (or whether a Tier II determination is pending); MDE reviews proposed amendments to county plans discharging to Tier II waters. In both cases, discharges to Tier II waters require a Tier II review [2.26.08.02.04-1(F)].

MDE has developed a cooperative approach to protecting Tier II waters. Monitoring and WQS programs work with the National Pollutant Discharge Elimination System (NPDES) permitting program to help screen for potential effects from new or expanded discharges and to develop permit conditions to minimize those effects and maintain existing high-quality waters. Outreach materials are available to educate county planners about Tier II waters, and geographic information system (GIS) shapefiles that planners can use to help locate Tier II waters within their jurisdictions have been developed.[1] That information provides Maryland county planners a way to determine early on whether their projects could affect Tier II waters.

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[1] More information about GIS is at http://www.gis.com/content/what-gis.

A list of recommendations for land-disturbing projects that are not able to implement a no-discharge alternative provides the following initial guidance:

1. Implementation of environmental site design (also known as low-impact development)—Design elements and practices must be approved for Tier II waters with opportunity provided for exploration of appropriate alternatives and justification for structural elements in the proposed designs.
2. Expanded riparian buffers—Buffers must be at a minimum of 100 feet; wider buffers may be required depending on slope and soil type.
3. Biological, chemical, and flow monitoring in the Tier II watershed—Applicants may be required to conduct biological assessments in conjunction with chemical, physical, and flow assessments to help determine the remaining assimilative capacity and cumulative impacts of current and future development. Depending on project specifics, additional monitoring may be required, such as the completion of a hydrogeologic study for a major mining project or additional pH monitoring because of impacts associated with instream grout applications seen in many common transportation projects.
4. Additional practices—Depending on the potential for project-specific effects on water quality, applicants may be required to implement other practices, such as enhanced sediment and erosion control practices or implementation of more environmentally protective alternatives.

If those general requirements cannot be implemented, applicants must submit a detailed hydrologic study and alternatives analysis to demonstrate that the assimilative capacity of a waterbody will be maintained. The assimilative capacity of a waterbody is typically site-specific and determined through studies of the waterbody. In terms of WQS, assimilative capacity is a measure of the capacity of a receiving water to assimilate additional pollutant(s) but still meet the applicable water quality criteria and designated uses.

3.3 Using Complementary Methods to Describe and Assess Biological Condition of Streams in Pennsylvania

Abstract

The Pennsylvania Department of Environmental Protection (PA DEP) has developed a new benthic macroinvertebrate index of biotic integrity (IBI) to assess the health of wadeable, freestone (e.g., high gradient, soft water) streams. Additionally, PA DEP calibrated a benthic macroinvertebrate Biological Condition Gradient (BCG) and is exploring using the BCG to more precisely describe biological characteristics in Pennsylvania streams. Potentially, the BCG can be used in conjunction with the IBI to identify aquatic life impairments and to describe the biological characteristics of waters assigned special protection. PA DEP is also exploring using a discriminant analysis model with additional taxonomic, habitat, and landscape parameters to describe exceptional value waters.

Describing Waters along a Gradient of Condition

Pennsylvania Department of Environmental Protection (PA DEP) has developed a new benthic macroinvertebrate index of biotic integrity (IBI) for the wadeable, freestone (high-gradient, soft-water) streams in Pennsylvania using the reference condition approach (PA DEP 2009). PA DEP has alternative assessment methods in place for other stream types (i.e., low-gradient pool-gliders, karst [limestone]-dominated). The IBI provides an integrated measure of the overall condition of a benthic macroinvertebrate community by combining multiple metrics into a single index value.
PA DEP uses the IBI to assess attainment of aquatic life uses.

A **metric** is a measurable aspect of a biological community that responds in a consistent, predictable manner to increasing anthropogenic stress. Examples of metrics include **taxa richness**, which is a measure of the number of different kinds of organisms (taxa) in a sample collection, and **% dominance**, which is a measure of which species compose the majority of organisms present in a sample collection.

To gain a more comprehensive view of an aquatic community, multiple types of metrics are combined into a **biological, or biotic, index**. The typical biological index may include information from 7 to 12 different metrics. The metric values are typically scored on a unitless scale of 0 to 100 and averaged to obtain a single value.

Additionally, PA DEP is exploring use of a Biological Condition Gradient (BCG) to describe the biological characteristics of freestone streams along a gradient of condition. PA DEP conducted a series of three expert workshops in 2006, 2007, and 2008 to calibrate a BCG along a gradient from minimally to heavily stressed conditions (PA DEP 2009). The BCG is a narrative model based on measurable attributes, or characteristics, of aquatic biological communities expected in natural conditions (e.g., presence of native taxa, some pollution tolerant taxa present but typically not dominant, absence of invasive species). Additionally, the BCG model includes attributes that describe interactions among biotic communities (e.g., food web dynamics), the spatial and temporal extent of stress, and the presence of naturally occurring habitats and landscape condition (for more information, see Tool # 2, *The Biological Condition Gradient*). To date, states and tribes that have applied the BCG have used the BCG attributes that describe the taxonomic composition of the resident aquatic biota and, where available, information on fish condition, for example lesions and abnormalities (BCG attributes I–VII) (see Table 2-2). Some states are exploring the application of additional attributes on food web dynamics, extent of stress, and landscape condition (BCG attributes VIII–X). These efforts are providing valuable information that will aid the U.S. Environmental Protection Agency (EPA) in further refining the BCG.

To develop the BCG for its streams, biologists from PA DEP, in conjunction with external taxonomic experts and scientists, e.g., the Delaware River Basin Commission, Western Pennsylvania Conservancy, and EPA, used the BCG attributes that characterize specific changes in community taxonomic composition (PA DEP 2009). For example, in the highest tiers of the BCG, locally endemic, native, and sensitive taxa are well represented (attributes I and II) and the relative abundances of pollution-tolerant organisms (attribute V) are typically lower. With increasing stress, more pollution-tolerant species may be found with concurrent loss of pollution-sensitive species (attribute VI). At the beginning of the expert workshops, the biologists first assigned or adjusted BCG attributes to each macroinvertebrate taxon (e.g., pollutant-sensitive or tolerant) and then reviewed taxa lists from samples representing minimally disturbed to severely disturbed site conditions (Figure 3-2). The evaluated samples included sites judged as either reference quality (e.g., at or close to minimally disturbed conditions) or heavily stressed based on specific selection criteria (PA DEP 2009). To further test the robustness of the BCG process, additional sites that were not part of the reference or heavily stressed sample groups were evaluated. Those sites represented a range of site conditions, including moderately to heavily stressed site conditions (non-reference and moderately stressed; see Figure 3-2). Using the BCG tier descriptions of predicted changes in the attributes as a guide, they assigned each site to one of the six BCG tiers.

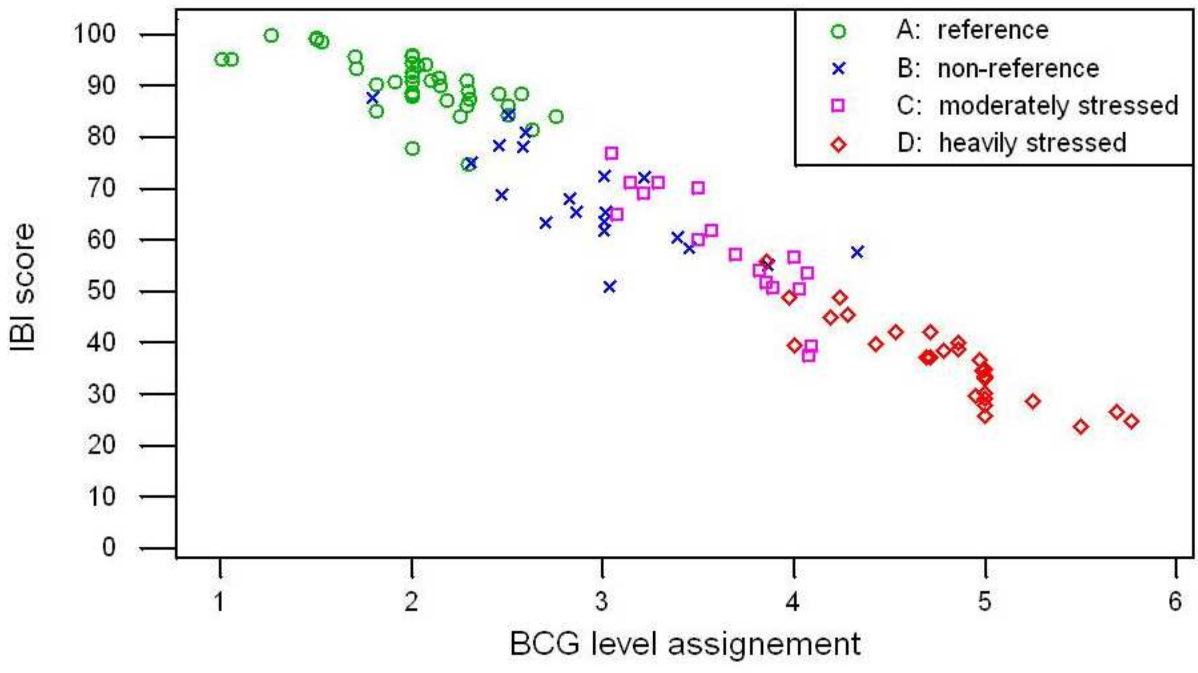

Figure 3-2. Comparison of calibrated BCG tier assignments (mean value) and IBI scores for freestone streams representing range of conditions from minimal to severely stressed.

For all the evaluated samples, PA DEP biologists analyzed the relationship between a sample's BCG tier assignment with its corresponding IBI score (PA DEP 2009). A strong correlation existed between the calibrated BCG tier assignments and the IBI scores (Figure 3-2). Based on these results, PA DEP is evaluating using the BCG to describe the biological characteristics of streams along a gradient of condition; for example, the reference sites clustered at IBI scores near 80 and above. Based on taxonomic information and without knowledge of the IBI scores, the experts assigned these sites to BCG tiers 1.5 to 2.5. BCG tier 2 represents close to natural conditions (e.g., minimal changes in structure and function relative to natural, or pristine, conditions; supports reproducing populations of native species of fish and benthic macroinvertebrates). This information can meaningfully convey to the public the biological characteristics of waters in the context of the Clean Water Act and the goal to protect aquatic life. Using both the IBI and BCG, PA DEP might be able to develop a cost-effective, publicly transparent approach to routinely monitor and assess the condition of its freestone streams and to help identify potential high-quality (HQ) or exceptional value (EV) streams.

Describing Exceptional Value Waters

Pennsylvania's regulations define waters of EV that are of unique ecological or geological significance. EV streams are given the highest level of protection and constitute a valuable subset of Pennsylvania's aquatic resources. To support protection of these waters, PA DEP is considering the use of a discriminant analysis model to evaluate the relationship between condition of the watershed, a stream, and its aquatic biota (e.g., the connection of riparian areas with a stream and the floodplain or the spatial extent of stressors and their sources in the watershed). PA DEP is evaluating the use of a discriminant model that incorporates measures of land use and physical habitat along with IBI scores and indicator taxa richness to make distinctions between EV and HQ waters. The abiotic measures PA DEP is using address habitat fragmentation and spatial and temporal extent of stress and are comparable to the national BCG model attributes IX (extent of stress) and X (ecosystem connectance). The results of this effort could potentially support decisions on where to target resources for sustainable, cost-effective protection of EV waters and healthy watersheds. Through this work, PA DEP is providing EPA valuable feedback on the technical development and potential program application for BCG attributes IX and X.

Potential Application to Support Protection of Waters of Highest Quality

PA DEP is exploring new approaches to help identify streams that are of the highest quality and might require special protection. For example, a stream might be found to meet the expected biological condition of an HQ or EV water based on its IBI score and BCG tier assignment. This information could be used to support further study to determine whether its designation should be as an HQ water or if it meets the additional criteria for designation as an EV water. When biological information is presented in context of a BCG framework, it is easier for the public to understand the status of the aquatic resources, including waters that are in excellent condition and require additional protection.

3.4 Use of Biological Assessments to Support Use Attainability Analysis in Ohio

Abstract

Ohio uses biological assessment information in conjunction with physical habitat assessments to strengthen use attainability analyses (UAAs) in the state. The technical and programmatic underpinnings for Ohio's use attainability determinations is the state's aquatic life use classification approach, which is based on the relationship between biology, habitat, and the potential for water quality improvement. Ohio's biological monitoring and assessment program provides timely, statewide information on the status of waterbodies and the data to support a UAA if needed, including when biological conditions improve and an upgrade of a designated use is warranted. Typically, in situations where the habitat needed to meet aquatic life uses is present, Ohio has taken management actions to address water quality issues and restore impairments.

In 1990 Ohio used biological assessment information to specify levels of biological condition for specific streams and rivers based on ecoregional reference sites. As a result, the state refined definitions of some aquatic life uses, adopted new ones, and assigned biological criteria to key uses to support a tiered approach to water quality management within the Ohio water quality standards (Table 3-3).

Table 3-3. Summary of Ohio's beneficial use designations for the protection of aquatic life in streams.

Beneficial use designation	Key attributes
Coldwater habitat (CWH)	Native cold water or cool water species; put and take trout stocking.
Exceptional warmwater habitat (EWH)	Unique, unusual, and highly diverse assemblage of fish and invertebrates.
Seasonal salmonid habitat (SSH)	Supports lake run steelhead trout fisheries.
Warmwater habitat (WWH)	Typical assemblages of fish and invertebrates, similar to least impacted reference conditions.
Limited warmwater habitat (LWH)	Temporary designations based on 1978 WQS. Predate Ohio tiered aquatic life use classification and were not subjected to UAA; being phased out as UAA are conducted for each LWH waterbody or segment. Most of the LWH waterbodies or segments have been redesignated as WWH or higher with the exception of some mine-drainage-affected segments that were designated LRW.
Modified warmwater habitat (MWH)	More tolerant assemblages of fish and macroinvertebrates are present relative to a WWH assemblage, but otherwise generally similar species to WWH present; irretrievable modifications of habitat preclude complete recovery to least impacted reference condition.
Limited resource water (LRW)	Fish and macroinvertebrates severely limited by physical habitat or other irretrievable condition; minimum protection afforded by the CWA.

Source: Ohio EPA, April 2004. http://www.epa.ohio.gov/portals/35/wqs/designation_summary.pdf.

When designating aquatic life uses, the quality of habitat is a major factor in a use attainability analysis (UAA) process to determine the potential for restoration and expected biological condition for streams and rivers in Ohio. If sufficient good habitat attributes are not present, such as higher quality substrates and sufficient instream cover, a determination about restorability is made. If habitat is sufficient or could be restored, it is assumed that any observed biological impairments are due to the effects of other stressors (e.g., metals, nutrients) that could be remediated through readily available water quality management options (e.g., permit conditions and/or best management practices [BMPs]) and the biological assemblage restored. The aquatic life use classifications are based on ecological conditions, and in 1990 biological criteria were developed to protect each use. Ohio's biological criteria include two indices based on stream fish assemblages (Index of Biological Integrity [IBI] and Modified Index of Well-Being [MIwb]) and one index based on stream macroinvertebrate assemblages (Invertebrate Community Index [ICI]). The biological criteria were developed based on regional reference conditions and are stratified by each of the state's five level 3 ecoregions and three site types (headwater, wadeable, and boatable sites).

Using these aquatic life use classifications, Ohio has been able to determine attainable levels of condition for streams and rivers. For example, in the mid-1980s biological surveys of Hurford Run, a small stream located in an urban/industrial area of Canton, Ohio, showed that the stream was severely impaired by toxic chemical pollutants and that some sites had no fish at all. Hurford Run is channelized for nearly its entire length. Because of the severity of the biological impairment, a UAA was conducted to determine if the warmwater habitat (WWH) aquatic life use was attainable and, if not, to determine the most appropriate designated use for the stream. Based on biological and habitat assessments, the most appropriate aquatic life uses for the different segments of Hurford Run could be determined. For example, very poor habitat quality from historical channelization in the *upper reach of Hurford Run* and the associated hydrological modifications (e.g., ephemeral flows) resulted in a limited warmwater habitat (LWH) designation for this upper reach.

The *middle reach of Hurford Run* has been subject to extensive, maintained channel modifications that also resulted in degraded habitat features, though water is always present. Channel maintenance practices resulting in poor-quality substrates, poorly developed pools and riffles, and a lack of instream cover preclude biological recovery to assemblages consistent with the WWH use, which indicated that the middle reach should be designated a modified warmwater habitat (MWH), reflecting the attainable biological potential for a channel-modified stream determined by scientific studies. The *lower reach of Hurford Run* was previously relocated and channelized, but over time the reach has naturally recovered sufficient good-quality habitat attributes, such as coarse substrates and better developed riffle and pool features associated with the WWH use for this ecoregion. Biological assessments confirmed the presence of aquatic assemblages typical of WWH. Based on this information, this segment was designated as WWH. The designated aquatic life uses reflect the current best possible condition in each segment of Hurford Run and provide a basis for management actions to ensure that the associated criteria are met and the use is protected. Numeric biological criteria have been established for key designated aquatic life uses, and a segment is listed on the 303(d) list if it is in nonattainment of the biological criteria. Additionally, the different segments are routinely monitored by the state and the condition reevaluated on a regular basis. If there is any information indicating that a higher use is being attained or could be attained, that water is considered for redesignation to the higher use.

Ohio has also used biological assessment data to refine its water quality criteria in some cases. For instance, when Ohio's aquatic life use classifications were established in 1978, Ohio established dissolved oxygen criteria to protect each designated use. Initially, a dissolved oxygen criterion of 6 mg/L as a minimum was established for exceptional warmwater habitat (EWH) waters to protect highly sensitive species supported by this use. However, analyses of ambient biological and chemical data suggested that the 6 mg/L minimum criterion was over-protective for EWH waters. Data showed a relationship between stressors and biological measures, with dissolved oxygen concentrations less than 5.0 mg/L being associated with IBI scores not in attainment of EWH biological criteria. And, in general, data showed that with dissolved oxygen greater than 5.0 mg/L, IBI scores are much more likely to attain EWH. These results were used to justify refining the EWH criteria to the current 6 mg/L average, 5 mg/L minimum (Ohio EPA 1996). The criterion revision also supported the redesignation of some rivers and streams from WWH to EWH.

Appendix B

Narrative BCG Model for the Northern Piedmont, Maryland

Biological Condition Gradient: A headwater stream catchment in the Northern Piedmont Region, Montgomery Co., MD

Hypothetical Example Draft 4/1/13

Example Scenario: The following Biological Condition Gradient provides a hypothetical series of sampling observations across a gradient (in space or time) of increasing inputs of pollutants or habitat modifications from increasing urbanization resulting in elevated sediments, nutrients, dissolved solids, and altered temperature regime. The example is based primarily on macroinvertebrate, fish and salamander assemblages in 1st to 3rd order streams (1:24,000 scale) with catchment areas ranging from 0.5 to 5 mi^2. These moderate gradient, scoured, cobble and gravel bottom stream systems lie within the Northern Piedmont ecoregion. Streams on the smallest end of the scale might naturally contain no fish but instead vertebrate predators are comprised of salamanders. Macroinvertebrates are typically sampled in the spring index period (March-May) while fishes and salamanders are sampled generally between July and September. Macroinvertebrates are sampled from multiple habitats including riffles, woody debris, leaf packs, and root mats. Example taxa are those typically encountered across such a gradient and are presented only as examples of the individual taxa that could be expected in the given environmental condition. There is no implied expectation that they must occur or that they would necessarily occur together.

Note: attribute assignments for some taxa (e.g., red salamander, two-line salamander) changed between this version and the final version (see Appendix D).

Narrative decision criteria for assigning sites to BCG levels -

Level 1 – Level 2 Natural Conditions (undisturbed to minimally disturbed). The panel felt that Level 1 sites, which are indistinguishable from pristine or undisturbed, would have strictly native taxa for all assemblages evaluated (fish, salamander, benthic macroinvertebrates) with no (non-natives present, some endemic species, and evidence of connectivity in the form of migratory fish. The presence of non-native species and loss of endemic species would move a site to the next level down on the gradient, Level 2. However, there are no sites within the piedmont that do not have some degree of disturbance, including legacy effects from agriculture and forestry from 100 to 200 years ago. This is typical situation for most of the North American continent. For practical reasons, Level 1 and highly rated level 2 (e.g. 2+) have been combined. These sites have excellent water quality and support habitat critical for native taxa. For macroinvertebrates, Level 2+ sites would have many highly sensitive taxa and relatively high richness and abundance of intermediate sensitive-ubiquitous taxa. Many of these taxa are characterized by having limited dispersal capabilities or are habitat specialists. Tolerant taxa are present but have low abundance. Presence of sensitive-rare, cold water indicator taxa such as the mayfly *Epeorus*, and stoneflies *Sweltsa* and *Talloperla* would be expected to occur.

Level 2 Near Natural (minimally disturbed). For fish, the panel decided that non-native species may be present, but they cannot exclude native species. A site that would be assigned to Level 2 must also maintain connectivity between the mainstem, associated wetlands and headwater streams so that migratory fish and amphibians (e.g., eel, lamprey, salamanders) are present or known to access the site.

Native top predators (e.g. brook trout) are present. The best fish site (upper Patuxent River) lacked brook trout, but reintroduction of reproducing native brook trout and access for migratory fish would raise this site to Level 2 status. Several sites rated as BCG level 3 supported habitat and water quality that would support a reproducing native brook population. These sites would then be rated as a level 2. The Long-tailed and Dusky salamanders were noted as two amphibians that panelists agreed would also help indicate Level 2 Piedmont streams given a complimentary fish community. Macroinvertebrate panelists believed that presence of several key taxa would help indicate Level 2 streams, especially coldwater indicator mayflies, stoneflies, and caddisflies (e.g, *Epeorus*, *Paraleptophlebia*, *Sweltsa*, and *Wormaldia*).

Level 3 Near Natural Habitat (loss of native taxa). Level 3 condition was generally considered a good quality condition by the panel. For macroinvertebrates, Level 3 sites should have several highly sensitive taxa and relatively high richness and abundance of intermediate sensitive-ubiquitous taxa. Taxa with intermediate tolerance may increase in richness and abundance. Tolerant taxa are somewhat more common but still have low abundance. Key sensitive taxa include the caddisfly *Diplectrona*, the mayfly *Ephemerella* and the stonefly *Amphinemura*. Panelists expected other key taxa to indicate Level 2 streams, especially coldwater indicator mayflies, stoneflies, and caddisflies (e.g, *Epeorus*, *Sweltsa*, and *Wormaldia*).

Level 3 – Level 4. For fish, the transition from Level 3 to Level 4 is characterized by increasing loss of sensitive species, and by increased abundance of tolerant species indicating nutrient enrichment and/or excess sedimentation. Salamander taxa would include the more generalist or tolerant Red Salamander and Two-lined Salamander, but sensitive Dusky may also occur. For macroinvertebrates, panelists agreed that as sites slipped toward Level 4, that highly sensitive macroinvertebrate taxa were more poorly represented but some intermediate sensitive-ubiquitous taxa populations were maintained. Although cool and coldwater indicator taxa such as *Dolophilodes*, *Diplectrona* and *Leuctra* are usually present, obvious increases in intermediate-tolerance and tolerant individuals were noted when compared to Level 2-3, driven primarily by increases in specific chironomid midgefly subfamilies.

Level 4 Significant Alteration in Aquatic Biota (Moderately Disturbed). Sensitive species and individuals are still present but in reduced numbers (e.g., approximately 10 – 30% of the community rather than 50% found in Level 3 streams). The experts generally agree that the persistence of some sensitive species indicates that their original ecosystem function is still maintained albeit at a reduced level. For example, Level 4 streams may have sculpins, but non-native species occur more frequently. Similarly, macroinvertebrate taxa such as *Diplectrona* and *Dolophilodes* may occur, but other key taxa such as *Ephemerella* and *Neophylax* are absent. These streams may harbor 2 to 3 salamander species (Dusky, Red, and Two-lined).

Level 4 – Level 5. The panel considered sites rated towards the lower end of Level 4 (e.g. approximately 10 - 15% of the sensitive species present) to be trending towards a markedly diminished aquatic community characteristic of the next level down, Level 5. Tolerant taxa predominant and sensitive species are either absent or present in very low numbers. Though not part of this evaluation, there can be increased evidence of physiological stress. Most notably in fish and amphibian communities, lesions, tumors, and other abnormalities are increasingly observed.

Level 5 Major Alteration in Aquatic Biota (Major level of disturbance). In Level 5, sensitive species and individuals may be present but their functional role is negligible within the system. Those sensitive taxa remaining are highly ubiquitous ones within the region having very good dispersal capabilities. Tolerant Two-lined salamanders might be the only salamander present. For macroinvertebrates, streams trending toward Level 5 revealed that highly sensitive macroinvertebrate taxa were usually absent and Chironomid midges (mostly tolerant Orthocladiinae and Chironomini) often comprised >50% of the community in Level 5 streams. Level 5 typically has abundant organisms that are mostly tolerant or intermediate tolerance, both native and introduced, and may have relatively high diversity within the tolerant organisms. Macroinvertebrate communities could have high or low overall diversity, but most representatives are opportunistic or pollution tolerant species.

Level 5 – Level 6. Transition from level 5 to level 6 is characterized by loss of remaining diversity to a depauperate community. Some highly tolerant organisms such as fathead minnows, brown bullhead, various maggot genera, tubificid and naidid worms, or physid snails may be very abundant, indicating extreme organic enrichment and hypoxia; or extreme low abundance and low richness of all organisms may indicate toxic conditions. Under hypoxic conditions, only those tolerant invertebrates adapted to living in low dissolved oxygen or can breathe atmospheric air may be present.

Level 6 Severe Alteration in Aquatic Biota (Extreme level of disturbance). In the Piedmont, these streams are heavily degraded from urbanization and/or industrialization and can range from having no aquatic life at all or harbor a severely depauperate community composed entirely of highly tolerant or tolerant invasive species adapted to hypoxia, extreme sedimentation and temperatures, or other toxic chemical conditions. In our exercise, panelist ratings were mixed for a couple of sites where some indicated a 6 while others indicated 5-. Experts who did not rate the site as a 6 indicated that the stream could get even worse.

Resource Condition "Categories"	Biological Condition Characteristics (Effects)
1 **Natural or native condition** *Native structural, functional and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability* **"Excellent" Streams** (Fully Supporting Designated Use)	**I Historically *documented, sensitive, long-lived, or regionally endemic* taxa** ➔ Depending on size of stream, one or more of the following are present: **Fishes:** Bridle Shiner, Brook Trout, Chesapeake Logperch, Maryland Darter, Trout Perch. May be absent in very small headwaters. **II Sensitive- *rare taxa*** ➔ The proportion of total richness represented by rare, specialist and vulnerable taxa is high, the following taxa are example represenatatives: **Ephemeroptera**: *Habrophlebia; Epeorus; Ephemera; Leucrocuta; Habrophlebiodes,;Paraleptophlebia, Drunella* **Plecoptera:** *Sweltsa*; *Talloperla; Eccoptura; Pteronarcys* **Trichoptera**: *Wormaldia Diplectrona*, *Rhyacophila*, *Dolophilodes*, *Psilotreta; Goera; Lepidostoma* **Diptera**: *Dixa,* Prodiamesinae; **Fishes***:* (may be basin and/or stream-size specific) Comely Shiner, N. Hogsucker, Margined Madtom, Shield Darter, Warmouth, Yellow Perch **Salamanders:** Long-tailed salamander, Dusky salamander **III Sensitive- *ubiquitous taxa*** ➔ Densities and richness of Sensitive-ubiquitous taxa are as naturally occurring; usually common or abundant. For macroinvertebrates, the following taxa are representative of this group for the region: **Plecoptera**: *Amphinemura, Acroneuria*; *Leuctra; Isoperla*; *Clioperla; Prostoia*, *Allocapnia,* **Ephemeroptera**: *Diphetor*, *Acentrella; Ephemerella, Ameletus; Serratella/Teloganopsis*; ***Odonata:*** *Cordulegaster; Lanthus* **Trichoptera**: *Neophylax*; *Rhyacophila*; *Pycnopsyche; Glossosoma* **Coleoptera:** *Oulimnius; Anchytarsus; Psephenus; Promoresia* **Diptera**: Diamesinae*; Hexatoma*; *Prosimulium;* **Fishes**: Blue Ridge Sculpin, Fantail Darter, Potomac Sculpin, Fallfish, Rosy-side Dace, River Chub, Common Shiner, Central Stoneroller **Salamanders:** Red Salamander **IV *Taxa of intermediate tolerance*** ➔ Densities and richness of *intermediate tolerance taxa* are as naturally occurs, usually low. The following taxa are representative of this category but may be entirely absent: **Ephemeroptera**: *Baetis; Stenonema*; *Caenis* **Odonata:** *Argia**;** Calopteryx; Boyeria* **Trichoptera**: *Chimarra*, *Cheumatopsyche, Hydropsyche*, *Polycentropus; Ironoquia* **Coleoptera**: *Helichus*; *Optioservus; Stenelmis;* **Megaloptera**: *Nigronia;* **Diptera**:

Chelifera, Clinocera; Tanytarsini, *Tipula, Simulium;* **Non-Insects**: *Crangonyx;* Enchytraeidae; **Fishes:** Tesselated Darter, Least Brook Lamprey, Longnose Dace, Pumpkinseed

V Tolerant *taxa*

- ➔ Occurrence and densities of Tolerant taxa are as naturally occur, usually rare or entirely absent.
- ➔ The following macroinvertebrate taxa are representative of this category: **Coleoptera:** Most Hydrophilidae and Dytiscidae genera; **Diptera**: most Chironomini and Orthocladiinae*;* Tabanidae, Stratiomyiidae; **Non-Insects**: Isopoda, Physidae, Hirudinae*;* Tubificidae; **Fishes**: tolerant generally absent; Yellow Bullhead, Red-breast Sunfish, Bluntnose Minnow, Golden Shiner, Mummichog typically absent; however, pioneering Blacknose Dace, Creek Chubs, White Sucker may be naturally common in smaller streams. Migratory species such as American Eel present. **Salamanders:** Two-lined Salamander

VI-i *Intolerant Non-native, intentionally introduced taxa*

- ➔ Non native taxa such as Brown Trout or Rainbow Trout, are absent or, if they occur, their presence does not displace native trout or alter structure and function.

VI-m *Intermediate Non-native taxa*

- ➔ Do not occur. Vertebrates (examples): Smallmouth Bass, Black Crappie, Longear Sunfish, Golden Redhorse. Invertebrates: Asian clam *(Corbicula)*

VI-m *Tolerant Non-native taxa*

- ➔ Do not occur. Vertebrates (examples): Common Carp, Goldfish, Fathead Minnow, Green Sunfish, Largemouth Bass

VII Physiological *condition of long-lived organisms*

- ➔ Anomalies are absent or rare; any that occur are consistent with naturally occurring incidence.

VIII *Ecosystem Function*

- ➔ Rates and characteristics of *life history (e.g., reproduction; immigration; mortality etc.)*, and materials

	exchange processes *(e.g., production; respiration; nutrient exchange; decomposition etc.)* are comparable to that of "natural" systems, but largely seasonally driven. ➔ The system is predominantly heterotrophic, sustained by leaf litter inputs from intact riparian areas, with low algal biomass; P/R<1 (Photosynthesis:Respiration ratio). **IX Spatial and temporal extent of detrimental effects** ➔ Not applicable- disturbance is limited to natural events such as storms, droughts, fire; earth-flows. A natural flow regime is maintained. Intermittency may be common in smallest streams in late-summer and early-fall. **X Ecosystem *connectance*** ➔ Reach is highly connected with groundwater, its floodplain, and riparian zone, and other reaches in the basin, at least annually. Allows for access to habitats and maintenance of seasonal cycles that are necessary for life history requirements, colonization sources and *refugia* for extreme events. Depending on size of stream, migratory fish such as American eel or sea lamprey occur (may be absent in smallest headwaters). Depending on local geology, reach is highly connected with groundwater, its floodplain, and riparian zone, and other reaches in the basin. Many Piedmont streams are coolwater due to natural groundwater input.

2 **Minimal changes in *structure* of the biotic community and minimal changes in *ecosystem function*** *Virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability* **Excellent and Good Streams** (Fully Supporting Designated Use)	**I Historically *documented, sensitive, long-lived, or regionally endemic* taxa** ➔ Depending on size of stream, one or more of the following are present: **Fishes:** Bridle Shiner, Brook Trout (top predator), Chesapeake Logperch, Maryland Darter, Trout Perch. May be absent in very small headwaters. **II Sensitive- *rare taxa*** ➔ The proportion of total richness represented by rare, specialist and vulnerable taxa is relatively high, the following taxa are example representatives: **Ephemeroptera**: *Habrophlebia; Epeorus; Ephemera; Leucrocuta; Habrophlebiodes,;Paraleptophlebia, Drunella* **Plecoptera:** *Sweltsa*; *Talloperla; Eccoptura; Pteronarcys* **Trichoptera**: *Wormaldia Diplectrona*, *Rhyacophila*, *Dolophilodes*, *Psilotreta; Goera; Lepidostoma* **Diptera**: *Dixa,* Prodiamesinae; **Fishes***:* (may be basin and stream-size specific) Comely Shiner, N. Hogsucker, Margined Madtom, Shield Darter, Warmouth, Yellow Perch **Salamanders:** Long-tailed salamander **III Sensitive- *ubiquitous taxa*** ➔ Densities and richness of Sensitive-ubiquitous taxa are as naturally occur; usually common or abundant. Attribute III taxa have higher abundance than Att. II taxa. For macroinvertebrates, the following taxa are representative of this group for the region: **Ephemeroptera**: *Acerpenna; Diphetor*; *Acentrella; Ephemerella, Ameletus; Serratella/Teloganopsis*; **Plecoptera**: *Amphinemura, Acroneuria*; *Leuctra; Isoperla*; *Clioperla; Prostoia*, *Allocapnia,* ***Odonata:*** *Cordulegaster; Lanthus* **Trichoptera**: *Neophylax*; *Rhyacophila*; *Pycnopsyche; Glossosoma* **Coleoptera:** *Oulimnius; Anchytarsus; Psephenus; Promoresia* **Diptera**: Diamesinae*; Hexatoma*; *Prosimulium;* **Fishes**: Blue Ridge Sculpin, Fantail Darter, Potomac Sculpin, Fallfish, Rosy-side Dace, River Chub, Common Shiner; Central Stoneroller low in abundance **Salamanders:** Dusky salamander, Red Salamander **IV *Taxa of intermediate tolerance*** ➔ Densities and richness of *intermediate tolerance taxa* are as naturally occurs, usually low but slight increases from Level 1. The following taxa are representative of this category: **Ephemeroptera**: *Baetis; Stenonema*; **Odonata:** *Calopteryx; Boyeria* **Trichoptera**: *Hydropsyche*, *Polycentropus;* **Coleoptera**: *Helichus*; *Optioservus;* **Megaloptera**: *Nigronia;* **Diptera**: *Chelifera,* Tanytarsini, *Tipula;* Tabanidae **Non-Insects**: *Crangonyx;* Enchytraeidae; **Fishes:** Tesselated Darter, Least Brook Lamprey, Longnose Dace,

	Pumpkinseed **V Tolerant *taxa*** ➔ Occurrence and densities of Tolerant taxa are as naturally occur, usually rare or entirely absent. ➔ The following taxa are representative of this Level: **Coleoptera:** Hydrophilidae; Dytiscidae; **Diptera**: *Hemerodromia;* most Chironomini and Orthocladiinae*;* Stratiomyiidae; **Non-Insects**: Isopoda, Physidae, Hirudinae*;* Tubificidae typically absent; **Fishes**: Yellow Bullhead, Red-breast Sunfish, Bluntnose Minnow typically absent; however, pioneering Blacknose Dace, Creek Chubs, White Sucker may be naturally common in smaller streams; Migratory species such as American Eel present. **Salamanders:** Two-lined Salamander may be naturally common **VI-i *Intolerant Non-native, intentionally introduced taxa*** ➔ Non native taxa such as Brown Trout or Rainbow Trout, are absent or, if they occur, their presence does not displace native trout or alter structure and function. **VI-m *Intermediate Non-native taxa*** ➔ Do not occur. Vertebrates (examples): Smallmouth Bass, Black Crappie, Longear Sunfish, Golden Redhorse. Invertebrates: Asian clam *(Corbicula)* **VI-t *Tolerant Non-native taxa*** ➔ Do not occur. Vertebrates (examples): Common Carp, Goldfish, Fathead Minnow, Green Sunfish, Largemouth Bass **VII Physiological condition of long-lived organisms** ➔ Any anomalies on fish are consistent with naturally occurring incidences and characteristics such as: rare occurrence of gill or anchor parasites, blackspot etc. ➔ Spawning areas of native fishes are evident during spawning season. **VIII *Ecosystem Function*** ➔ Rates and characteristics of *life history* (e.g., reproduction; immigration; mortality etc.), and materials

	exchange processes (e.g., production; respiration; nutrient exchange; decomposition e*tc.)* are unimpaired and not significantly different from the range of natural variability. ➔ The system is predominantly heterotrophic, sustained by leaf litter inputs from intact riparian areas; P/R is<1. **IX Spatial and temporal extent of detrimental effects** ➔ Extent is limited to small pockets or brief periods. **X *Ecosystem connectance*** ➔ Unimpaired access to habitats, and maintenance of seasonal cycles, which are necessary to fulfill *life history requirements*, and to provide colonization sources and *refugia* for extreme events. Connectance on a local scale (floodplain, tributaries) remains good; eels and lamprey may be absent due to dams and other flow obstructions. Non-native sunfish (centrachidae) may occur due to ponds and dams.

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Evident changes in *structure* of the biotic community and minimal changes in *ecosystem function*

Some changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa but <u>Sensitive-ubiquitous</u> taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system

Excellent to Good Streams

(Fully Supporting Designated Use)

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I Historically *documented, sensitive, long-lived, or regionally endemic* taxa

➔ These taxa absent or occur sporadically; **Fishes** (may be basin and stream-size specific): Bridle Shiner, Brook Trout, Chesapeake Logperch, Maryland Darter, Trout Perch.

➔

II Sensitive- *rare taxa*

➔ The proportion of total richness represented by rare, specialist and vulnerable taxa is reduced compared to Resource Level 2; the following taxa are example representatives: **Ephemeroptera**: *Paraleptophlebia* may occur in low densities **Plecoptera:** *Eccoptura* present but others are somewhat rare or absent **Trichoptera**: *Wormaldia Diplectrona*, *Rhyacophila*, *Dolophilodes* common **Diptera**: *Dixa,* Prodiamesinae; **Fishes***:* (may be basin and stream-size specific) N. Hogsucker, Margined Madtom rare or absent **Salamanders:** Long-tailed salamander absent.

III Sensitive- *ubiquitous taxa*

Densities and richness of Sensitive-ubiquitous taxa are common or abundant; taxa with slightly broader temperature or sediment tolerance may be favored. All sensitive taxa combined (Att. II+III) make up >50% of taxa and abundance. The following taxa are representative of this Level for the region: **Ephemeroptera**: *Acerpenna; Ephemerella, Diphetor; Ameletus; Serratella/Teloganopsis*; ***Odonata:*** *Cordulegaster; Lanthus* **Plecoptera**: *Amphinemura, Acroneuria*; *Leuctra; Isoperla*; *Clioperla; Prostoia*, *Allocapnia,* **Trichoptera**: *Neophylax*; *Pycnopsyche;* **Coleoptera:** *Oulimnius; Anchytarsus; Psephenus; Promoresia* **Diptera**: Diamesinae*; Hexatoma*; *Prosimulium;* **Fishes**: Blue Ridge Sculpin, Fantail Darter, Potomac Sculpin, Fallfish, Rosy-side Dace, River Chub **Salamanders:** Dusky salamander infrequent or occurs in low numbers, Red Salamander common.

IV *Taxa of intermediate tolerance*

➔ Densities and richness of *intermediate tolerance taxa* increased compared to Level 2 but generally comprise less than half total richness and abundance. The following taxa are representative of this Level: **Ephemeroptera**: *Baetis; Stenonema*; *Caenis* **Odonata:** *Argia***;** *Calopteryx; Boyeria* **Trichoptera**: *Chimarra*, *Cheumatopsyche, Hydropsyche*, *Polycentropus; Ironoquia* **Coleoptera**: *Helichus*; *Optioservus; Stenelmis;* **Megaloptera**: *Nigronia;* **Diptera**: Empididae*,* Tanytarsini, *Tipula, Simulium;* Tabanidae **Non-Insects**: *Crangonyx;* Enchytraeidae; **Fishes:** Tesselated Darter, Least Brook Lamprey, Longnose Dace, Pumpkinseed

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V Tolerant *taxa*

- Occurrence and densities of Tolerant taxa are present but with only slight increases in abundance observed. For vertebrates, tolerant taxa make up less than half of total abundance but typically comprise only one-fourth of invertebrates.
- The following taxa are representative of this Level: **Coleoptera:** Hydrophilidae; Dytiscidae; **Diptera**: *Hemerodromia;* Chironomini and Orthocladiinae may be abundant*;* Stratiomyiidae; **Non-Insects**: Isopoda, Physidae, Hirudinae*;* Tubificidae uncommon; Yellow Bullhead, Red-breast Sunfish, Bluntnose Minnow absent; however, pioneering Blacknose Dace, Creek Chubs, White Sucker may be naturally common in smaller streams. Migratory species such as American Eel may be absent. **Salamanders:** Two-lined Salamanders common

VI-i *Intolerant Non-native, intentionally introduced taxa*

- Non native taxa such as Brown Trout or Rainbow Trout, may be absent or, if they occur, their presence may displace native trout (through competition) or alter structure and function.

VI-m *Intermediate Non-native taxa*

- May occur. Fishes (examples): Smallmouth Bass, Black Crappie, Longear Sunfish, Golden Redhorse. Invertebrates: Asian clam *(Corbicula)*

VI-t *Tolerant Non-native taxa*

- May occur at low densities comprising small fraction of all fishes. Fishes (examples): Common Carp, Goldfish, Fathead Minnow, Green Sunfish, Largemouth Bass

VII Physiological condition of long-lived organisms

- Incidence of *anomalies* such as gill parasites, anchor parasites, blackspot, etc., is low; serious anomalies such as tumors or deformities are essentially absent.
- Environmental quality is sufficient to fully support reproduction of most long-lived species.

	VIII *Ecosystem Function* ➔ Increased temperature and algal metabolism rarely causes small diurnal sags in dissolved oxygen, compensated by adequate aeration from turbulence over riffle areas. ➔ Algal biomass somewhat exceeds what can be utilized by resident grazers, resulting in evidence of die-back and slight downstream export of sloughed material. ➔ Patchy loss of high food quality riparian vegetation (e.g., oak; maple, beech) and elevated temperature, results in decreased growth and survival of some specialized shredder taxa (Pteronarcidae, Peltoperlidae) with replacement by eurythermic shredders capable of utilizing lower quality organic matter (Limnephilidae (*Ironoquia*; some Tipulidae). **IX Spatial and temporal extent of detrimental effects** ➔ Filamentous green algae occur in small patches within reaches; Low dissolved oxygen levels occur only during the high temperature and low flow summer periods. ➔ Interstitial spaces, within the substrate of pools, are filled with fine sediment resulting in localized losses of interstitial habitats but riffle areas continue to provide adequate water flow and oxygen through interstitial habitats. **X *Ecosystem connectance*** ➔ Connectance on a local scale (floodplain, tributaries) remains good; eels and lamprey may be absent due to dams and other flow obstructions. Non-native sunfish (centrachidae) may occur due to ponds and dams. ➔ Some downcutting has resulted in a patchy decrease in *connectance* of the stream from its floodplain except at unusually high flows. ➔ Thinning and patchy loss of riparian vegetation has altered the microclimate of the surrounding landscape causing a decrease in survival and reproductive success of adult mayflies and stoneflies.

4 **Moderate changes in *structure* of the biotic community and minimal changes in *ecosystem function*** *Moderate changes in structure due to replacement of some Sensitive-ubiquitous taxa by more tolerant taxa, but reproducing populations of some Sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes*	**I Historically *documented, sensitive, long-lived, or regionally endemic* taxa** ➔ These taxa are typically absent; Brook Trout do not ocurr. **II Sensitive- *rare taxa*** ➔ The proportion of total richness represented by rare, specialist and vulnerable taxa is reduced. Presence could represent colonization sources from upstream, unaffected tributaries: Most prevalent representatives include**:** **Ephemeroptera**:*; Habrophlebiodes, Paraleptophlebia* **Plecoptera:** *Eccoptura;* **Trichoptera**: *Diplectrona*, *Rhyacophila*, *Dolophilodes* **Diptera**: Prodiamesinae; **Fishes***:* (may be basin and stream-size specific) N. Hogsucker, Margined Madtom **Salamanders:** Long-tailed salamander absent **III Sensitive- *ubiquitous taxa*** ➔ Densities and richness of Sensitive-ubiquitous taxa are reduced but populations of some taxa maintained. The following taxa are most representative: **Ephemeroptera**: *Acerpenna; Acentrella;* the more silt-tolerant Ephemerellid *Eurylophella* may out number *Ephemerella,* ***Odonata:*** *Cordulegaster; Lanthus* **Plecoptera**: reduced *Amphinemura, Acroneuria*; *Isoperla*; *Allocapnia,* **Trichoptera**: *Neophylax*; *Rhyacophila*; *Pycnopsyche* infrequent*;* **Coleoptera:** *Oulimnius; Psephenus;* **Diptera**: Diamesinae*; Hexatoma*; *Prosimulium;* **Fishes**: Two or 3 fish species occur but make up only a fraction of individuals: Blue Ridge Sculpin, Fantail Darter, Potomac Sculpin, Fallfish, Rosy-side Dace, River Chub; the Central Stoneroller may dominate in low sediment situations; **Salamanders:** Dusky salamander infrequent or occurs in low numbers; Red Salamander present. **IV *Taxa of intermediate tolerance*** ➔ Densities and richness of *intermediate tolerance taxa* have increased. The following taxa are potential representatives within this Level: **Ephemeroptera**: *Baetis; Stenonema*; *Caenis* **Odonata:** *Argia***;** *Calopteryx; Boyeria* **Trichoptera**: *Chimarra*, *Cheumatopsyche, Hydropsyche*, *Polycentropus; Ironoquia* **Coleoptera**: *Helichus*; *Optioservus; Stenelmis;* **Megaloptera**: *Corydalus; Nigronia;* **Diptera**: *Chelifera, Atherix;* Tanytarsini, *Tipula, Simulium;* Tabanidae **Non-Insects**: *Crangonyx;* Enchytraeidae; **Fishes:** Tesselated Darter, Least Brook Lamprey, Longnose Dace **V Tolerant *taxa***

Good to Fair Quality Streams (may be Partially Supporting Designated Use)	➔ Occurrence and densities of Tolerant taxa have increased but do not exhibit excessive dominance. ➔ The following macroinvertebrate taxa are representative of this category: **Coleoptera:** Hydrophilidae; Dytiscidae; **Diptera**: *Hemerodromia;* Chironomini and Orthocladiinae are abundant*;* Stratiomyiidae; **Non-Insects**: Isopoda, Physidae, Hirudinae*;* Tubificidae but in low densities; **Fishes**: Yellow Bullhead, Red-breast Sunfish, Bluntnose Minnow common; pioneering Blacknose Dace, Creek Chubs, White Sucker may be naturally common in smaller streams. **Salamanders:** Increased prevalence of Two-lined Salamander **VI-i *Intolerant Non-native, intentionally introduced taxa*** ➔ Non native taxa such as Brown Trout or Rainbow Trout typically absent **VI-m *Intermediate Non-native taxa*** ➔ May occur at higher densities compared to Level 3. Fishes (examples): Smallmouth Bass, Black Crappie, Longear Sunfish, Golden Redhorse. Invertebrates: Asian clam *(Corbicula)* **VI-t *Tolerant Non-native taxa*** ➔ May occur at higher densities or may tend to dominate. Fishes (examples): Common Carp, Goldfish, Fathead Minnow, Green Sunfish, Largemouth Bass **VII Physiological condition of long-lived organisms** ➔ Incidence of anomalies such as blackspot and gill and anchor parasites is slightly higher than expected ➔ Occurrence of tumors, lesions and deformities is rare. ➔ Filamentous bacteria (e.g., *Sphaerotilus* (sewage “fungus”) might be observed attached to macroinvertebrates. **VIII Ecosystem *Function*** ➔ Increased available nutrients increase algal productivity causing increased diatom, macro-algae and macrophyte biomass, and consequently lowering evening dissolved oxygen levels and increasing daytime oxygen levels. Invertebrate biomass is high (unless limited by sediment) but production has shifted to result in greater biomass of intermediate tolerance organisms than sensitive organisms. For example, filter-feeders utilizing suspended material shift increase while scrapers decline and are replaced by deposit feeders. The suspended organic matter load somewhat exceeds what can be utilized by resident filterers resulting in increased levels of exported material. Sloughing of excess macro-algae and macrophyte biomass results in increased downstream export of course particulate organic matter. ➔ The system is becoming more autotrophic due to algal photosynthesis. The P/R ratio shows a slight increase.

	IX Spatial and temporal extent of detrimental effects ➔ Increased macrophyte and algal biomass extends downstream beyond the confluence with the next tributary; filamentous algae first appears in the stream as temperatures warm in late spring; pools and depositional areas are silt-filled; the interstitial spaces in the substrate of runs is becoming obstructed by sand and silt. ➔ Early morning low dissolved oxygen levels occur occasionally during late spring through fall in perennial reaches. ➔ In very small streams, open canopies result in excessive insolation to dry streambeds, adding desiccation stress to adult or diapausing stages of sensitive populations requiring high humidity or moisture levels. **X Ecosystem *connectance*** ➔ Filling of interstitial spaces obstructs access to hyporheic zone for early instar mayfly/stonefly nymphs, eliminating nursery areas and *refugia* for storm-events and low flows. Adult stoneflies from upstream reaches continue to oviposit but reproductive success is limited; stonefly/mayfly nymphs continue to colonize by drift, with limited success ➔ Poorly managed culverts on some tributaries impede fish passage and access to some spawning areas. Connectance disrupted; eels and lamprey typically absent due to dams and other flow obstructions. Non-native sunfish (centrachidae) occur due to ponds and dams.

5	
Major changes in *structure* of the biotic community and moderate changes in *ecosystem function* *Sensitive taxa are absent or markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build-up or export of unused materials.*	**I *Historically documented, sensitive, long-lived, or regionally endemic* taxa** ➔ Typically absent; poor water quality, compaction of substrate, and elevated temperature regime preclude occurrence of these taxa. **II *Sensitive- rare, specialist, vulnerable* taxa with narrow environmental requirements** ➔ Typically absent; only the rare occurrence of individual representatives of specialist and vulnerable taxa with no evidence of successful reproduction; may be controlled by drift and dependent on proximity to colonization source. **III *Sensitive- ubiquitous* taxa** ➔ Either absent or present in very low numbers, indicating impaired recruitment and/or reproduction; may be controlled by drift and proximity to colonization source ➔ Elevated temperature, sediment, nutrients and other urban chemicals detrimental to most mayflies and stoneflies **IV *Opportunist or facultative* taxa of intermediate tolerance** ➔ Typically diverse and abundant compared. In low sediment conditions, filter-feeding invertebrates such as caddisflies (e.g., *Cheumatopsyche*; *Chimarra*) and filter-feeding dipterans (e.g., Tanytarsini, *Simulium*) may occur in very high numbers and are favored by suspended organic matter as well as dense growths of the macro-algae *Cladophora* (provides attachment sites for netspinning Hydropsychidae); piercing herbivores (e.g., hydroptilid caddisflies) also respond positively to increase in *Cladophora;* grazer/gatherers such as *Optioservus* and *Stenelmis* may be reduced. ➔ High sediment conditions may favor swimmers (e.g., *Baetis*) and sprawlers (e.g. many Orthocladiinae) over clingers but overall abundance of all taxa reduced; **Fishes**: Facultative species reduced or absent. **V *Tolerant taxa*** ➔ Tolerant taxa often dominate total abundance; dominance by tolerant collector-gatherers (e.g., Orthocladiini; Chironomini)*;* deposit-feeders such as Tubificidae increased ➔ Relative abundance of non-insects often equal to or higher than relative abundance of insects ➔ Atmospheric breathers such as Tabanidae, Stratiomyiidae; Hemiptera, Physid snails common; adult Hydrophilidae; Dytiscidae may be common in pool areas **Fishes**: Yellow Bullhead, Red-breast Sunfish, Bluntnose Minnow common; Blacknose Dace, Creek Chubs, White Sucker dominate. **Salamanders:** Two-lined Salamander is the only salamander found but occurs less frequently compared to higher Levels.

Fair to Poor Quality Streams (Non-Supporting of Designated Use)	**VI-i** ***Intolerant Non-native, intentionally introduced taxa*** ➔ Non native taxa such as Brown Trout or Rainbow Trout typically absent **VI-m** ***Intermediate Non-native taxa*** ➔ May occur at higher densities compared to Level 4. Fishes (examples): Smallmouth Bass, Black Crappie, Longear Sunfish, Golden Redhorse. Invertebrates: Asian clam *(Corbicula)* **VI-t** ***Tolerant Non-native taxa*** ➔ May dominate the entire fish assemblage. Common Carp, Goldfish, Fathead Minnow, Green Sunfish, Largemouth Bass **VII Physiological condition of long-lived organisms** ➔ Biomass of young of year age classes is low; overall fish biomass is reduced; sex ratio of remaining fish ≠ equal 1 ➔ Occurrence of parasitic infestations and disease is common (e.g., mite attachment and nematode incidence in macroinvertebrate specimens; fish parasites, eroded fins, lesions, etc.). ➔ Incidence of serious anomalies such as tumors and anatomical deformities is higher than expected ➔ Bacterial infestations from *Sphaerotilus* (sewage "fungus") may be present and attached to many organisms causing increased mortality with heavy infestations; ammonia toxicity may occur with organic enrichment. **VIII** ***Ecosystem Function*** ➔ High algal photosynthetic activity results in daytime dissolved oxygen supersaturation accompanied by nighttime dissolved oxygen levels less than 5 ppm. Extremely high algal biomass significantly alters the habitat structure of the substrate (mainly in less turbid waters) ➔ The P/R ratio is significantly > 1; the system is predominantly autotrophic (unless limited by sediment and turbidity) ➔ Loss of coarse particulate shredders and alteration of bacterial decomposer community contributes to build-up and/or export of unused organic matter ➔ Mechanisms for nutrient spiraling (biota, habitat complexity) are significantly simplified and less efficient resulting in increased export of nutrients from the system. **IX Spatial and temporal extent of detrimental effects**

	➔ Substrate has become armored by increased sediment loading, altered flow regime and altered channel morphology resulting in compaction of interstitial space habitat, leaving only patches of well-scoured gravel substrate in high-gradient riffle areas; armoring is resistant to spring scouring events, preventing annual spring sediment flushing and re-sorting of substrate. ➔ Near complete canopy removal results in all day insolation of stream and surrounding land surface causing abnormally elevated temperature regime in early spring and late fall, or excessive drying and heating of substrates in small stream channels where diapausing stages require hyporheic flow or high ambient moisture/humidity; increasing number of impoundments in watershed alter temperature and flow regime causing unnaturally elevated seasonal temperature cues and results in failures of *life history requirements.* ➔ Impervious surfaces from urbanization steepen hydrographs causing unnatural flow patterns and scouring. Extreme headwater streams (zero and first-order) have been buried and piped. **X Ecosystem *connectance*** ➔ Lateral connectance to floodplain areas is eliminated except at peak flows, due to altered channel morphology (e.g., headcutting) caused by human intervention (bank riprapping, dredging) and altered flow regime. ➔ All appropriate high quality spawning gravel in upstream areas is destroyed by silt deposition, preventing spawning of white suckers and facultative species, leaving only mature adults or transient individuals. Poorly managed culverts on some tributaries impede fish passage and access to some spawning areas. Connectance disrupted; eels and lamprey typically absent due to dams and other flow obstructions. Non-native sunfish (centrachidae) occur due to ponds and dams. ➔ Lack of riparian vegetation and protruding coarse substrates eliminates habitat for adult flying aquatic insects, reducing survival and reproduction of resident organisms and reducing successful recruitment of immigrating organisms (i.e., flight dispersal of ovipositing females). ➔ In small streams, open canopies result in excessive insolation to dry streambeds, adding desiccation stress to adult or diapausing stages of sensitive populations.

6 **Severe changes in *structure* of the biotic community and major loss of *ecosystem function*** *Extreme changes in structure; wholesale changes in taxonomic composition; extreme alterations from normal densities and distributions; organism condition is often poor; ecosystem functions are severely altered* **Poor Quality Streams** (Non-Supporting of	**I *Historically documented*, *sensitive, long-lived, regionally endemic* taxa** ➔ Poor water quality, compaction of substrate, and elevated temperature regime preclude occurrence of these taxa. **II *Sensitive- rare taxa*** ➔ These taxa are absent due to poor water quality, elevated temperature regime, alteration of habitat, loss of riparian zone, etc. Cool and cold water taxa extirpated. **III *Sensitive- ubiquitous* taxa** ➔ Absent due to above listed factors, though an occasional transient individual, usually in poor condition, may be collected. May be controlled by drift and dependent on proximity to colonization source. Cool and cold water taxa extirpated. **IV Taxa of intermediate tolerance** ➔ Heavy sediment and low dissolved oxygen limit filter-feeding insects and other macroinvertebrate representatives of this group are severely reduced in density and richness, or are absent; chronic ammonia toxicity may occur with organic enrichment; low dissolved oxygen levels and inordinately high levels of urban runoff chemicals toxic to Group I-III and many Group IV organisms. ➔ **Fishes:** Intermediate tolerance fishes may be entirely absent or reduced to a few individuals. **V *Tolerant taxa*** ➔ Low dissolved oxygen conditions preclude survival of many insect taxa except those with special adaptations to deficient oxygen conditions (e.g., Chironomini; Oligochaeta; atmospheric breathers such as mosquitoes Culicidae; Hemiptera; adult Hydrophilidae; Dytiscidae) may be prevalent. ➔ The macroinvertebrate assemblage may be dominated by tolerant non-insects (Physid snails; Planariidae; Oligochaeta; Hirudinea; etc.) ➔ High sediment and lack of large woody debris favors burrowers, climbers, and sprawlers over clinger taxa ➔ Tolerant invertebrate predators rare (e.g., *Argia*) ➔ **Fishes**: low in abundance or absent, represented mainly by Blacknose Dace, Green Sunfish, Bluntnose Minnow, Creek Chub

Designated Use)	**VI-i *Intolerant Non-native, intentionally introduced taxa*** ➔ Non native taxa such as Brown Trout or Rainbow Trout absent **VI-m *Intermediate Non-native taxa*** ➔ May be absent Fishes (examples): Smallmouth Bass, Black Crappie, Longear Sunfish, Golden Redhorse. Invertebrates: Asian clam *(Corbicula)* **VI-t *Tolerant Non-native taxa*** ➔ May dominate the entire fish assemblage. Common Carp, Goldfish, Fathead Minnow, Green Sunfish, Largemouth Bass **VII Physiological condition of long-lived organisms** ➔ Fish biomass is very low; individuals that are collected appear to be transients and are in poor condition ➔ Incidence of parasitic infestations and disease is high; anatomical deformities and/or tumors are common ➔ Minimal evidence of recruitment or reproduction except some extremely tolerant groups may have high production; young of year age classes are absent; bacterial infestations (e.g., *Sphaerotilus* (sewage “fungus”)) may be present and attached to most macroinvertebrates ➔ Diatom and chironomid mentum deformities common in areas with toxic runoff **VIII *Ecosystem Function*** ➔ Water quality has degraded to such an extent that algal photosynthesis is negligible. ➔ Decomposition of organic matter creates P/R markedly <1; the system is predominantly heterotrophic as a result of high bacterial respiration and minimal photosynthesis. ➔ Reproductive success is very low. ➔ Recruitment of emigrating organisms into upstream and downstream habitats is impaired due to low fecundity and high mortality rates of resident biota.

	IX Spatial and temporal extent of detrimental effects ➔ The *reach* and all tributaries are affected by widespread alteration of within stream conditions as a result of severely altered land-use and poor water quality. Extreme headwater streams (zero and first-order) have been buried and piped. Urban runoff-related chemicals (grease, soaps) may deposit in both riffles and pool areas, extensive coating or smothering of substrate observed in pools. **X *Ecosystem connectance*** ➔ *Catchment*-wide land-use disturbance and alteration of stream morphology has affected all tributaries eliminating sources of recruitment and destroying spawning habitat. Connectance disrupted; eels and lamprey absent due to dams and other flow obstructions. Non-native sunfish (centrachidae) occur due to ponds and dams. ➔ Physical and chemical requirements to fulfill *life history functions* (e.g., seasonal temperature cues for mating behavior and egg development; intact nursery habitats; optimal levels of dissolved gases, overhanging vegetation for adult insects mating and resting, etc.) are severely disrupted resulting in very low reproductive success and high mortality rates.

Appendix C

BCG Attribute Assignments – Macroinvertebrates

Table C1. Maryland Northern Piedmont BCG attribute assignments for macroinvertebrates. This list is sorted by order, family, then by taxon. # Individs refers to the total number of individuals in the dataset that was used for this project. Older systematics are retained for some taxa that underwent taxonomic revision over the course of the data collection period. This list is inclusive of taxa that might occur in the region (but not all of these taxa occur in the project dataset).

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
x		Pelcorhynchidae		PELCORHYNCHIDAE	0
x				Aelosoma	0
x				GASTROPODA	0
x				GORDIOIDEA	2
5				HIRUDINEA	2
x				HYDRACHNIDIA	0
x				MOLLUSCA	0
x				NEMATODA	0
x				NEMATOMORPHA	0
5				OLIGOCHAETA	57
x				PODOCOPA	0
5				TURBELLARIA	0
x	Amphipoda	Crangonyctidae		CRANGONYCTIDAE	0
4	Amphipoda	Crangonyctidae		Crangonyx	830
x	Amphipoda	Crangonyctidae		Stygobromus	28
3	Amphipoda	Crangonyctidae		Synurella	7
x	Amphipoda	Gammaridae		GAMMARIDAE	0
4	Amphipoda	Gammaridae		Gammarus	671
x	Amphipoda	Gammaridae		Stygonectes	8
4	Amphipoda	Hyalellidae		Hyalella	31
4	Amphipoda	Hyalellidae		HYALELLIDAE	0
4	Amphipoda	NULL		AMPHIPODA	0
x	Amphipoda	NULL		CRUSTACEA (Amphipoda)	0
4	Basommatophora	Ancylidae		ANCYLIDAE	0
4	Basommatophora	Ancylidae		Ferrissia	34
5	Basommatophora	Lymnaeidae		Fossaria	0
5	Basommatophora	Lymnaeidae		Lymnaea	1
5	Basommatophora	Lymnaeidae		LYMNAEIDAE	0
5	Basommatophora	Lymnaeidae		Pseudosuccinea	1
x	Basommatophora	Lymnaeidae		Radix	0
5	Basommatophora	Lymnaeidae		Stagnicola	29
5	Basommatophora	Physidae		Physa	118
5	Basommatophora	Physidae		Physella	0
5	Basommatophora	Physidae		PHYSIDAE	17
5	Basommatophora	Planorbidae		Gyraulus	4
5	Basommatophora	Planorbidae		Helisoma	6
5	Basommatophora	Planorbidae		Menetus	13
5	Basommatophora	Planorbidae		Planorbella	4
4	Basommatophora	Planorbidae		PLANORBIDAE	0
x	Basommatophora	Planorbidae		Promenetus	0

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
4	Branchiobdellida	NULL		BRANCHIOBDELLIDA	0
x	Calanoida	NULL		CALANOIDA	0
x	Cladocera	Daphniidae		Daphnia	0
x	Cladocera	Daphniidae		DAPHNIIDAE	0
x	Cladocera	NULL		CLADOCERA	0
x	Coleoptera	Curculionidae		CURCULIONIDAE	0
x	Coleoptera	Dryopidae		DRYOPIDAE	0
4	Coleoptera	Dryopidae		Helichus	66
4	Coleoptera	Dytiscidae		Agabetes	0
4	Coleoptera	Dytiscidae		Agabus	17
x	Coleoptera	Dytiscidae		Copelatus	2
x	Coleoptera	Dytiscidae		Coptotomus	0
4	Coleoptera	Dytiscidae		Cybister	0
4	Coleoptera	Dytiscidae		Deronectes	0
4	Coleoptera	Dytiscidae		Derovatellus	0
4	Coleoptera	Dytiscidae		DYTISCIDAE	7
x	Coleoptera	Dytiscidae		Helocombus	1
4	Coleoptera	Dytiscidae		Hydroporus	49
4	Coleoptera	Dytiscidae		Laccophilus	0
4	Coleoptera	Dytiscidae		Neoporus	9
4	Coleoptera	Dytiscidae		Oreodytes	0
4	Coleoptera	Dytiscidae		Uvarus	0
4	Coleoptera	Elmidae		Ancyronyx	61
4	Coleoptera	Elmidae		Dubiraphia	141
x	Coleoptera	Elmidae		ELMIDAE	19
4	Coleoptera	Elmidae		Macronychus	73
3	Coleoptera	Elmidae		Microcylloepus	29
4	Coleoptera	Elmidae		Optioservus	715
3	Coleoptera	Elmidae		Oulimnius	931
2	Coleoptera	Elmidae		Promoresia	35
5	Coleoptera	Elmidae		Stenelmis	1082
4	Coleoptera	Gyrinidae		Dineutus	15
4	Coleoptera	Gyrinidae		GYRINIDAE	0
4	Coleoptera	Gyrinidae		Gyrinus	7
x	Coleoptera	Haliplidae		HALIPLIDAE	0
5	Coleoptera	Haliplidae		Haliplus	1
5	Coleoptera	Haliplidae		Peltodytes	10
x	Coleoptera	Hydrochidae		HYDROCHIDAE	0
4	Coleoptera	Hydrophilidae		Berosus	6
4	Coleoptera	Hydrophilidae		Cymbiodyta	2
4	Coleoptera	Hydrophilidae		Derallus	0
4	Coleoptera	Hydrophilidae		Enochrus	2

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
4	Coleoptera	Hydrophilidae		Helochares	0
4	Coleoptera	Hydrophilidae		Helophorus	2
4	Coleoptera	Hydrophilidae		Hydrobius	11
4	Coleoptera	Hydrophilidae		Hydrochara	0
4	Coleoptera	Hydrophilidae		Hydrochus	2
4	Coleoptera	Hydrophilidae		HYDROPHILIDAE	0
4	Coleoptera	Hydrophilidae		Hydrophilus	0
4	Coleoptera	Hydrophilidae		Laccobius	0
4	Coleoptera	Hydrophilidae		Sperchopsis	1
4	Coleoptera	Hydrophilidae		Tropisternus	8
x	Coleoptera	NULL		COLEOPTERA	0
x	Coleoptera	Psephenidae		Dicranopselaphus	0
3	Coleoptera	Psephenidae		Ectopria	20
x	Coleoptera	Psephenidae		PSEPHENIDAE	0
3	Coleoptera	Psephenidae		Psephenus	270
3	Coleoptera	Ptilodactylidae		Anchytarsus	379
3	Coleoptera	Ptilodactylidae		PTILODACTYLIDAE	0
x	Coleoptera	Sciritidae		Scirites	0
x	Coleoptera	Scirtidae		Cyphon	0
x	Coleoptera	Scirtidae		SCIRTIDAE	0
x	Collembola	Isotomidae		ISOTOMIDAE	0
x	Collembola	Isotomidae		Isotomurus	40
x	Collembola	NULL		Agrenia	0
x	Collembola	NULL		COLLEMBOLA	0
x	Collembola	Sminthuridae		Bourletiella	2
x	Copepoda	NULL		COPEPODA	0
4	Decapoda	Cambaridae		CAMBARIDAE	1
4	Decapoda	Cambaridae		Cambarus	12
4	Decapoda	Cambaridae		Orconectes	5
6	Decapoda	Cambaridae		Procambarus	0
x	Decapoda	NULL		CRUSTACEA (Decopoda)	0
x	Decapoda	Palaemonidae		Palaemonetes	1
x	Decapoda	Palaemonidae		PALAEMONIDAE	0
x	Diptera	Athericidae		ATHERICIDAE	0
3	Diptera	Athericidae		Atherix	1
2	Diptera	Blephariceridae		Blepharicera	0
2	Diptera	Blephariceridae		BLEPHARICERIDAE	0
4	Diptera	Ceratopogonida		Dasyhelea	4
4	Diptera	Ceratopogonidae		Alluaudomyia	0
4	Diptera	Ceratopogonidae		Atrichopogon	1
4	Diptera	Ceratopogonidae		Bezzia	38
4	Diptera	Ceratopogonidae		Ceratopogon	69
4	Diptera	Ceratopogonidae		CERATOPOGONIDAE	4

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
4	Diptera	Ceratopogonidae		Culicoides	13
4	Diptera	Ceratopogonidae		Mallochohelea	0
3	Diptera	Ceratopogonidae		Probezzia	88
x	Diptera	Ceratopogonidae		Serromyia	0
4	Diptera	Ceratopogonidae		Sphaeromias	1
4	Diptera	Ceratopogonidae		Stilobezzia	4
x	Diptera	Chaoboridae		CHAOBORIDAE	0
4	Diptera	Chaoboridae		Chaoborus	8
5	Diptera	Chironomidae	Tanypodinae	Ablabesmyia	0
3	Diptera	Chironomidae	Tanypodinae	Apsectrotanypus	0
4	Diptera	Chironomidae	Orthocladiinae	Brillia	0
x	Diptera	Chironomidae	Tanypodinae	Brundiniella	0
5	Diptera	Chironomidae	Orthocladiinae	Cardiocladius	0
4	Diptera	Chironomidae	Orthocladiinae	Chaetocladius	0
4	Diptera	Chironomidae		CHIRONOMIDAE	449
x	Diptera	Chironomidae	Chironominae	CHIRONOMINAE	0
5	Diptera	Chironomidae	Chironominae	CHIRONOMINI	3363
5	Diptera	Chironomidae	Chironominae	Chironomus	0
x	Diptera	Chironomidae	Chironominae	Cladopelma	0
5	Diptera	Chironomidae	Chironominae	Cladotanytarsus	0
5	Diptera	Chironomidae	Tanypodinae	Clinotanypus	0
5	Diptera	Chironomidae	Tanypodinae	Conchapelopia	0
2	Diptera	Chironomidae	Chironominae	Constempellina	0
5	Diptera	Chironomidae	Orthocladiinae	Corynoneura	0
5	Diptera	Chironomidae	Orthocladiinae	Cricotopus	0
x	Diptera	Chironomidae	Orthocladiinae	Cricotopus/Orthocladius	0
5	Diptera	Chironomidae	Chironominae	Cryptochironomus	0
5	Diptera	Chironomidae	Chironominae	Cryptotendipes	0
3	Diptera	Chironomidae	Chironominae	Demicryptochironomus	0
3	Diptera	Chironomidae	Diamesinae	Diamesa	0
4	Diptera	Chironomidae	Diamesinae	DIAMESINAE	4093
5	Diptera	Chironomidae	Chironominae	Dicrotendipes	0
5	Diptera	Chironomidae	Orthocladiinae	Diplocladius	0
5	Diptera	Chironomidae	Chironominae	Endochironomus	0
5	Diptera	Chironomidae	Orthocladiinae	Eukiefferiella	7
x	Diptera	Chironomidae	Orthocladiinae	Georthocladius	0
5	Diptera	Chironomidae	Chironominae	Glyptotendipes	0
2	Diptera	Chironomidae	Orthocladiinae	Heleniella	0
3	Diptera	Chironomidae	Orthocladiinae	Heterotrissocladius	0
5	Diptera	Chironomidae	Orthocladiinae	Hydrobaenus	0
x	Diptera	Chironomidae	Chironominae	Kiefferulus	0
x	Diptera	Chironomidae	Tanypodinae	Krenopelopia	0
3	Diptera	Chironomidae	Orthocladiinae	Krenosmittia	0
4	Diptera	Chironomidae	Tanypodinae	Labrundinia	0

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
4	Diptera	Chironomidae	Tanypodinae	Larsia	0
5	Diptera	Chironomidae	Orthocladiinae	Limnophyes	0
x	Diptera	Chironomidae	Orthocladiinae	Lopescladius	0
x	Diptera	Chironomidae	Tanypodinae	Macropelopia	0
x	Diptera	Chironomidae	Tanypodinae	Meropelopia	0
x	Diptera	Chironomidae	Orthocladiinae	Metriocnemus	0
4	Diptera	Chironomidae	Chironominae	Micropsectra	0
5	Diptera	Chironomidae	Chironominae	Microtendipes	0
4	Diptera	Chironomidae	Orthocladiinae	Nanocladius	0
5	Diptera	Chironomidae	Tanypodinae	Natarsia	0
x	Diptera	Chironomidae	Tanypodinae	Nilotanypus	0
x	Diptera	Chironomidae	Chironominae	Nilothauma	0
x	Diptera	Chironomidae	Prodiamesinae	Odontomesa	0
x	Diptera	Chironomidae	Chironominae	Omisus	0
5	Diptera	Chironomidae	Orthocladiinae	ORTHOCLADIINAE	26553
x	Diptera	Chironomidae	Orthocladiinae	Orthocladiinae A	0
x	Diptera	Chironomidae	Orthocladiinae	Orthocladiinae B	0
5	Diptera	Chironomidae	Orthocladiinae	Orthocladius	0
x	Diptera	Chironomidae	Orthocladiinae	Orthocladius (Symp.) lignicola	0
x	Diptera	Chironomidae	Diamesinae	Pagastia	0
x	Diptera	Chironomidae	Chironominae	Pagastiella	0
3	Diptera	Chironomidae	Orthocladiinae	Parachaetocladius	0
5	Diptera	Chironomidae	Chironominae	Parachironomus	0
x	Diptera	Chironomidae	Chironominae	Paracladopelma	0
5	Diptera	Chironomidae	Orthocladiinae	Parakiefferiella	0
x	Diptera	Chironomidae	Chironominae	Paralauterborniella	0
x	Diptera	Chironomidae	Tanypodinae	Paramerina	0
4	Diptera	Chironomidae	Orthocladiinae	Parametriocnemus	0
4	Diptera	Chironomidae	Orthocladiinae	Paraphaenocladius	0
x	Diptera	Chironomidae	Orthocladiinae	Parasmittia	0
5	Diptera	Chironomidae	Chironominae	Paratanytarsus	0
5	Diptera	Chironomidae	Chironominae	Paratendipes	0
x	Diptera	Chironomidae	Orthocladiinae	Paratrichocladius	0
5	Diptera	Chironomidae	Tanypodinae	Pentaneura	0
5	Diptera	Chironomidae	Chironominae	Phaenopsectra	0
5	Diptera	Chironomidae	Chironominae	Polypedilum	0
3	Diptera	Chironomidae	Diamesinae	Potthastia	0
5	Diptera	Chironomidae	Tanypodinae	Procladius	0
2	Diptera	Chironomidae	Prodiamesinae	Prodiamesa	0
2	Diptera	Chironomidae	Prodiamesinae	PRODIAMESINAE	7
5	Diptera	Chironomidae	Orthocladiinae	Psectrocladius	0
4	Diptera	Chironomidae	Tanypodinae	Psectrotanypus	0
2	Diptera	Chironomidae	Orthocladiinae	Pseudorthocladius	0
x	Diptera	Chironomidae	Orthocladiinae	Psilometriocnemus	0

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
4	Diptera	Chironomidae	Orthocladiinae	Rheocricotopus	0
4	Diptera	Chironomidae	Tanypodinae	Rheopelopia	0
4	Diptera	Chironomidae	Orthocladiinae	Rheosmittia	0
4	Diptera	Chironomidae	Chironominae	Rheotanytarsus	0
x	Diptera	Chironomidae	Chironominae	Saetheria	0
4	Diptera	Chironomidae	Orthocladiinae	Smittia	0
3	Diptera	Chironomidae	Chironominae	Stempellina	0
3	Diptera	Chironomidae	Chironominae	Stempellinella	0
5	Diptera	Chironomidae	Chironominae	Stenochironomus	0
5	Diptera	Chironomidae	Chironominae	Stictochironomus	0
x	Diptera	Chironomidae	Orthocladiinae	Stilocladius	0
3	Diptera	Chironomidae	Chironominae	Sublettea	0
x	Diptera	Chironomidae	Orthocladiinae	Symposiocladius	0
2	Diptera	Chironomidae	Diamesinae	Sympotthastia	0
x	Diptera	Chironomidae	Diamesinae	Syndiamesa	0
x	Diptera	Chironomidae	Orthocladiinae	Synorthocladius	0
4	Diptera	Chironomidae	Tanypodinae	TANYPODINAE	2136
5	Diptera	Chironomidae	Tanypodinae	Tanypus	0
4	Diptera	Chironomidae	Chironominae	Tanytarsini	2993
5	Diptera	Chironomidae	Chironominae	Tanytarsus	0
5	Diptera	Chironomidae	Orthocladiinae	Thienemanniella	0
2	Diptera	Chironomidae	Tanypodinae	Thienemannimyia	0
5	Diptera	Chironomidae	Chironominae	Tribelos	0
4	Diptera	Chironomidae	Tanypodinae	Trissopelopia	0
4	Diptera	Chironomidae	Orthocladiinae	Tvetenia	0
4	Diptera	Chironomidae	Orthocladiinae	Unniella	0
4	Diptera	Chironomidae	Orthocladiinae	Xylotopus	0
x	Diptera	Chironomidae	Orthocladiinae	Zalutschia	0
4	Diptera	Chironomidae	Chironominae	Zavrelia	0
x	Diptera	Chironomidae	Chironominae	Zavreliella	0
4	Diptera	Chironomidae	Tanypodinae	Zavrelimyia	0
4	Hemiptera	Corixidae		Sigara	0
5	Diptera	Culcidae		Wyeomyia	0
5	Diptera	Culicidae		Aedes	5
5	Diptera	Culicidae		Anopheles	0
5	Diptera	Culicidae		Culex	2
5	Diptera	Culicidae		CULICIDAE	0
2	Diptera	Dixidae		Dixa	24
x	Diptera	Dixidae		Dixella	5
2	Diptera	Dixidae		DIXIDAE	0
x	Diptera	Dolichopodidae		DOLICHOPODIDAE	5
4	Diptera	Empididae		Chelifera	102
4	Diptera	Empididae		Clinocera	725
x	Diptera	Empididae		Dolichocephala	0

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
4	Diptera	Empididae		EMPIDIDAE	10
4	Diptera	Empididae		Hemerodromia	311
4	Diptera	Empididae		Neoplasta	5
x	Diptera	Ephydridae		EPHYDRIDAE	1
x	Diptera	Muscidae		Limnophora	2
x	Diptera	Muscidae		MUSCIDAE	0
x	Diptera	NULL		DIPTERA	0
x	Diptera	Pelcorhynchidae		Glutops	0
5	Diptera	Psychodidae		Pericoma	2
5	Diptera	Psychodidae		Psychoda	5
5	Diptera	Psychodidae		PSYCHODIDAE	0
4	Diptera	Ptychopteridae		Bittacomorpha	1
4	Diptera	Ptychopteridae		Ptychoptera	3
x	Diptera	Ptychopteridae		PTYCHOPTERIDAE	0
x	Diptera	Sarcophagidae		SARCOPHAGIDAE	0
x	Diptera	Sciomyzidae		SCIOMYZIDAE	1
3	Diptera	Simuliidae		Cnephia	18
x	Diptera	Simuliidae		Ectemnia	0
3	Diptera	Simuliidae		Prosimulium	6024
x	Diptera	Simuliidae		SIMULIIDAE	4
4	Diptera	Simuliidae		Simulium	1700
4	Diptera	Simuliidae		Stegopterna	680
x	Diptera	Simuliidae		Twinia	0
4	Diptera	Stratiomyidae		Allognosta	0
4	Diptera	Stratiomyidae		Nemotelus	0
4	Diptera	Stratiomyidae		Odontomyia	0
4	Diptera	Stratiomyidae		Oxycera	0
4	Diptera	Stratiomyidae		STRATIOMYIDAE	0
4	Diptera	Stratiomyidae		Stratiomys	0
x	Diptera	Syrphidae		Chrysogaster	1
x	Diptera	Syrphidae		SYRPHIDAE	0
5	Diptera	Tabanidae		Chrysops	46
5	Diptera	Tabanidae		TABANIDAE	0
5	Diptera	Tabanidae		Tabanus	3
x	Diptera	Tanyderidae		Protoplasa	1
x	Diptera	Thaumaleidae		Thaumalea	0
4	Diptera	Tipulidae		Antocha	875
3	Diptera	Tipulidae		Cryptolabis	0
3	Diptera	Tipulidae		Dicranota	152
4	Diptera	Tipulidae		Erioptera	6
x	Diptera	Tipulidae		Eriopterini	0
x	Diptera	Tipulidae		Helius	1
3	Diptera	Tipulidae		Hexatoma	121

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
x	Diptera	Tipulidae		Leptotarsus	0
4	Diptera	Tipulidae		Limnophila	1
4	Diptera	Tipulidae		Limonia	13
3	Diptera	Tipulidae		Molophilus	7
4	Diptera	Tipulidae		Ormosia	29
3	Diptera	Tipulidae		Pedicia	1
4	Diptera	Tipulidae		Pilaria	1
4	Diptera	Tipulidae		Pseudolimnophila	238
x	Diptera	Tipulidae		Rhabdomastix	4
4	Diptera	Tipulidae		Tipula	525
4	Diptera	Tipulidae		TIPULIDAE	1
x	Ephemeroptera	Ameletidae		AMELETIDAE	0
3	Ephemeroptera	Ameletidae		Ameletus	782
3	Ephemeroptera	Baetidae		Acentrella	152
3	Ephemeroptera	Baetidae		Acerpenna	132
3	Ephemeroptera	Baetidae		BAETIDAE	7
4	Ephemeroptera	Baetidae		Baetis	867
x	Ephemeroptera	Baetidae		Barbaetis	0
4	Ephemeroptera	Baetidae		Callibaetis	2
2	Ephemeroptera	Baetidae		Centroptilum	113
4	Ephemeroptera	Baetidae		Cloeon	0
3	Ephemeroptera	Baetidae		Diphetor	263
3	Ephemeropthetera	Baetidae		Plauditus	5
3	Ephemeroptera	Baetidae		Procloeon	7
2	Ephemeroptera	Baetiscidae		Baetisca	1
x	Ephemeroptera	Baetiscidae		BAETISCIDAE	0
x	Ephemeroptera	Caenidae		CAENIDAE	0
4	Ephemeroptera	Caenidae		Caenis	102
2	Ephemeroptera	Ephemerellidae		Attenella	0
3	Ephemeroptera	Ephemerellidae		Dannella	13
2	Ephemeroptera	Ephemerellidae		Drunella	47
3	Ephemeroptera	Ephemerellidae		Ephemerella	7195
3	Ephemeroptera	Ephemerellidae		EPHEMERELLIDAE	7
3	Ephemeroptera	Ephemerellidae		Eurylophella	732
3	Ephemeroptera	Ephemerellidae		Serratella	249
x	Ephemeroptera	Ephemerellidae		Teloganopsis*	9
3	Ephemeroptera	Ephemerellidae		Timpanoga	0
3	Ephemeroptera	Ephemeridae		Ephemera	11
x	Ephemeroptera	Ephemeridae		EPHEMERIDAE	0
4	Ephemeroptera	Ephemeridae		Hexagenia	0
x	Ephemeroptera	Ephemeridae		Pentagenia	0
2	Ephemeroptera	Heptageniidae		Cinygmula	4
2	Ephemeroptera	Heptageniidae		Epeorus	341
2	Ephemeroptera	Heptageniidae		Heptagenia	0

*for future work, this should be assigned to attribute '3' because the most common Serratella in this region is now called Teloganopsis (and Serratella is an attribute 3 taxon)

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
x	Ephemeroptera	Heptageniidae		HEPTAGENIIDAE	5
2	Ephemeroptera	Heptageniidae		Leucrocuta	11
x	Ephemeroptera	Heptageniidae		Maccaffertium	318
2	Ephemeroptera	Heptageniidae		Nixe	0
4	Ephemeroptera	Heptageniidae		Stenacron	48
4	Ephemeroptera	Heptageniidae		Stenonema	974
3	Ephemeroptera	Isonychiidae		Isonychia	438
x	Ephemeroptera	Isonychiidae		ISONYCHIIDAE	0
2	Ephemeroptera	Leptophlebiidae		Habrophlebia	44
3	Ephemeroptera	Leptophlebiidae		Leptophlebia	47
3	Ephemeroptera	Leptophlebiidae		LEPTOPHLEBIIDAE	27
3	Ephemeroptera	Leptophlebiidae		Paraleptophlebia	323
x	Ephemeroptera	Metretopodidae		METRETOPODIDAE	0
x	Ephemeroptera	Metretopodidae		Siphloplectron	0
x	Ephemeroptera	NULL		EPHEMEROPTERA	0
x	Ephemeroptera	Oligoneuridae		OLIGONEURIIDAE	0
x	Ephemeroptera	Polymitarcyidae		POLYMITARCYIDAE	0
3	Ephemeroptera	Potamanthidae		Anthopotamus	1
3	Ephemeroptera	Potamanthidae		POTAMANTHIDAE	0
x	Ephemeroptera	Siphlonuridae		SIPHLONURIDAE	0
4	Ephemeroptera	Siphlonuridae		Siphlonurus	23
4	Ephemeroptera	Tricorythidae		TRICORYTHIDAE	0
4	Ephemeroptera	Tricorythidae		Tricorythodes	1
4	Haplotaxida	Enchytraeidae		ENCHYTRAEIDAE	30
4	Haplotaxida	Naididae		NAIDIDAE	122
4	Haplotaxida	Naididae		Nais	0
5	Haplotaxida	Lumbricidae		LUMBRICIDAE	7
5	Hemiptera	Belostomatidae		Belostoma	1
5	Hemiptera	Belostomatidae		BELOSTOMATIDAE	0
5	Hemiptera	Corixidae		CORIXIDAE	0
4	Hemiptera	Corixidae		Palmacorixa	0
5	Hemiptera	Corixidae		Trichocorixa	0
x	Hemiptera	Gerridae		Aquarius	1
x	Hemiptera	Gerridae		GERRIDAE	0
x	Hemiptera	Gerridae		Gerris	0
x	Hemiptera	Gerridae		Limnoporus	1
x	Hemiptera	Gerridae		Metrobates	0
x	Hemiptera	Gerridae		Trepobates	0
x	Hemiptera	Mesoveliidae		MESOVELIIDAE	0
x	Hemiptera	Naucoridae		NAUCORIDAE	0
x	Hemiptera	Nepidae		NEPIDAE	0
5	Hemiptera	Nepidae		Ranatra	0
5	Hemiptera	Notonectidae		Notonecta	0
x	Hemiptera	Notonectidae		NOTONECTIDAE	0

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
x	Hemiptera	Saldidae		SALDIDAE	0
x	Hemiptera	Veliidae		Microvelia	5
x	Hemiptera	Veliidae		Rhagovelia	0
x	Hemiptera	Veliidae		VELIIDAE	0
4	Hoplonemertea	Tetrastemmatidae		Prostoma	72
x	Hoplonemertea	Tetrastemmatidae		TETRASTEMMATIDAE	0
5	Isopoda	Asellidae		ASELLIDAE	0
x	Isopoda	Asellidae		Asellus	2
5	Isopoda	Asellidae		Caecidotea	133
5	Isopoda	Asellidae		Lirceus	155
x	Isopoda	NULL		CRUSTACEA (Isopoda)	0
5	Isopoda	NULL		ISOPODA	0
x	Lepidoptera	Cosmopterygidae		COSMOPTERYGIDAE	0
x	Lepidoptera	Cosmopterygidae		Pyroderces	0
x	Lepidoptera	Crambidae		Petrophila	2
x	Lepidoptera	Noctuidae		Bellura	0
x	Lepidoptera	Noctuidae		NOCTUIDAE	0
x	Lepidoptera	Noctuidiae		Archanara	1
x	Lepidoptera	NULL		LEPIDOPTERA	1
x	Lepidoptera	Pyralidae		PYRALIDAE	0
x	Lepidoptera	Tortricidae		TORTRICIDAE	0
5	Lumbriculida	Lumbriculidae		LUMBRICULIDAE	30
4	Lumbriculida	Lumbriculidae		Lumbriculus/Stylodrilus	0
4	Megaloptera	Corydalidae		Chauliodes	5
x	Megaloptera	Corydalidae		CORYDALIDAE	0
4	Megaloptera	Corydalidae		Corydalus	22
3	Megaloptera	Corydalidae		Nigronia	192
x	Megaloptera	NULL		MEGALOPTERA	0
4	Megaloptera	Sialidae		SIALIDAE	0
4	Megaloptera	Sialidae		Sialis	39
6	Mesogastropoda	Bithyniidae		Bithynia	0
6	Mesogastropoda	Bithyniidae		BITHYNIIDAE	0
5	Mesogastropoda	Hydrobiidae		Amnicola	0
x	Mesogastropoda	Hydrobiidae		Hydrobia	0
4	Mesogastropoda	Hydrobiidae		HYDROBIIDAE	0
4	Mesogastropoda	Pleuroceridae		Goniobasis	5
5	Mesogastropoda	Pleuroceridae		Leptoxis	63
4	Mesogastropoda	Pleuroceridae		PLEUROCERIDAE	0
4	Mesogastropoda	Valvatidae		Valvata	0
4	Mesogastropoda	Valvatidae		VALVATIDAE	0
4	Mesogastropoda	Viviparidae		Campeloma	0
4	Mesogastropoda	Viviparidae		VIVIPARIDAE	0
4	Mesogastropoda	Viviparidae		Viviparus	0

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
x	Neuroptera	Sisyridae		Climacia	0
x	Neuroptera	Sisyridae		SISYRIDAE	0
4	Odonata	Aeshnidae		Aeshna	1
x	Odonata	Aeshnidae		AESHNIDAE	0
4	Odonata	Aeshnidae		Basiaeschna	0
4	Odonata	Aeshnidae		Boyeria	44
4	Odonata	Calopterygidae		CALOPTERYGIDAE	0
4	Odonata	Calopterygidae		Calopteryx	106
4	Odonata	Calopterygidae		Hetaerina	2
4	Odonata	Coenagrionidae		Argia	71
4	Odonata	Coenagrionidae		COENAGRIONIDAE	1
4	Odonata	Coenagrionidae		Enallagma	27
4	Odonata	Coenagrionidae		Ischnura	1
x	Odonata	Coenagrionidae		Nehalennia	0
3	Odonata	Cordulegastridae		Cordulegaster	21
x	Odonata	Cordulegastridae		CORDULEGASTRIDAE	0
x	Odonata	Corduliidae		CORDULIIDAE	0
4	Odonata	Corduliidae		Macromia	3
3	Odonata	Corduliidae		Somatochlora	3
x	Odonata	Corduliidae		Tetragoneuria	0
4	Odonata	Gomphidae		Arigomphus	0
4	Odonata	Gomphidae		Dromogomphus	0
x	Odonata	Gomphidae		Erpetogomphus	0
4	Odonata	Gomphidae		GOMPHIDAE	15
4	Odonata	Gomphidae		Gomphus	2
3	Odonata	Gomphidae		Hagenius	2
3	Odonata	Gomphidae		Lanthus	12
x	Odonata	Gomphidae		Ophiogomphus	2
4	Odonata	Gomphidae		Progomphus	0
4	Odonata	Gomphidae		Stylogomphus	27
4	Odonata	Libellulidae		Erythemis	0
4	Odonata	Libellulidae		Leucorrhinia	0
4	Odonata	Libellulidae		Libellula	0
x	Odonata	Libellulidae		LIBELLULIDAE	0
x	Odonata	Libellulidae		Pachydiplax	1
x	Odonata	NULL		ODONATA (Anisoptera)	0
x	Odonata	NULL		ODONATA (Zygoptera)	0
x	Ostracoda	NULL		OSTRACODA	0
5	Pharyngobdellida	Erpobdellidae		ERPOBDELLIDAE	0
5	Pharyngobdellida	Erpobdellidae		Mooreobdella	0
3	Plecoptera	Capniidae		Allocapnia	136
x	Plecoptera	Capniidae		Capnia	0
3	Plecoptera	Capniidae		CAPNIIDAE	5

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
3	Plecoptera	Capniidae		Paracapnia	46
2	Plecoptera	Chloroperlidae		Alloperla	7
2	Plecoptera	Chloroperlidae		CHLOROPERLIDAE	11
2	Plecoptera	Chloroperlidae		Haploperla	41
2	Plecoptera	Chloroperlidae		Perlinella	0
2	Plecoptera	Chloroperlidae		Sweltsa	50
2	Ephemerotera	Leptophlebiidae		Habrophlebiodes	32
3	Plecoptera	Leuctridae		Leuctra	681
3	Plecoptera	Leuctridae		LEUCTRIDAE	5
2	Plecoptera	Leuctridae		Paraleuctra	0
2	Plecoptera	Leuctridae		Zealeuctra	0
3	Plecoptera	Nemouridae		Amphinemura	4055
2	Plecoptera	Nemouridae		Nemoura	20
3	Plecoptera	Nemouridae		NEMOURIDAE	2
2	Plecoptera	Nemouridae		Ostrocerca	12
2	Plecoptera	Nemouridae		Paranemoura	0
3	Plecoptera	Nemouridae		Prostoia	1111
2	Plecoptera	Nemouridae		Shipsa	0
2	Plecoptera	Nemouridae		Soyedina	1
x	Plecoptera	NULL		PLECOPTERA	3
2	Plecoptera	Peltoperlidae		Peltoperla	1
2	Plecoptera	Peltoperlidae		PELTOPERLIDAE	0
2	Plecoptera	Peltoperlidae		Tallaperla	58
3	Plecoptera	Perlidae		Acroneuria	153
3	Plecoptera	Perlidae		AGNETINA	7
3	Plecoptera	Perlidae		Eccoptura	106
2	Plecoptera	Perlidae		Neoperla	1
2	Plecoptera	Perlidae		Paragnetina	8
3	Plecoptera	Perlidae		Perlesta	34
3	Plecoptera	Perlidae		PERLIDAE	5
3	Plecoptera	Perlodidae		Clioperla	48
2	Plecoptera	Perlodidae		Cultus	8
2	Plecoptera	Perlodidae		Diploperla	22
x	Plecoptera	Perlodidae		Helopicus	4
3	Plecoptera	Perlodidae		Isoperla	205
2	Plecoptera	Perlodidae		Malirekus	1
2	Plecoptera	Perlodidae		PERLODIDAE	5
2	Plecoptera	Perlodidae		Remenus	0
x	Plecoptera	Pteronarcyidae		PTERONARCYIDAE	0
2	Plecoptera	Pteronarcyidae		Pteronarcys	24
3	Plecoptera	Taeniopterygidae		Oemopteryx	44
3	Plecoptera	Taeniopterygidae		Strophopteryx	381

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
2	Plecoptera	Taeniopterygidae		Taenionema	1
3	Plecoptera	Taeniopterygidae		TAENIOPTERYGIDAE	0
3	Plecoptera	Taeniopterygidae		Taeniopteryx	46
5	Rhynchobdellida	Glossiphoniidae		GLOSSIPHONIIDAE	0
5	Rhynchobdellida	Glossiphoniidae		Helobdella	0
x	Rhynchobdellida	Glossiphoniidae		Placobdella	1
5	Rhynchobdellida	Piscicolidae		Piscicola	1
5	Rhynchobdellida	Piscicolidae		PISCICOLIDAE	9
2	Trichoptera	Brachycentridae		BRACHYCENTRIDAE	0
3	Trichoptera	Brachycentridae		Brachycentrus	0
3	Trichoptera	Brachycentridae		Micrasema	9
x	Trichoptera	Calamoceratidae		CALAMOCERATIDAE	0
3	Trichoptera	Calamoceratidae		Heteroplectron	2
4	Trichoptera	Dipseudopsidae		DIPSEUDOPSIDAE	0
4	Trichoptera	Dipseudopsidae		Phylocentropus	1
3	Trichoptera	Glossosomatidae		Agapetus	6
3	Trichoptera	Glossosomatidae		Glossosoma	87
3	Trichoptera	Glossosomatidae		GLOSSOSOMATIDAE	0
x	Trichoptera	Helicopsychidae		Helicopsyche	15
4	Trichoptera	Hydropsychidae		Ceratopsyche	48
4	Trichoptera	Hydropsychidae		Cheumatopsyche	3459
3	Trichoptera	Hydropsychidae		Diplectrona	1104
4	Trichoptera	Hydropsychidae		Homoplectra	6
4	Trichoptera	Hydropsychidae		Hydropsyche	2329
x	Trichoptera	Hydropsychidae		HYDROPSYCHIDAE	12
x	Trichoptera	Hydropsychidae		Macrostemum	1
2	Trichoptera	Hydropsychidae		Parapsyche	0
4	Trichoptera	Hydropsychidae		Potamyia	12
4	Trichoptera	Hydroptilidae		Hydroptila	29
x	Trichoptera	Hydroptilidae		HYDROPTILIDAE	0
4	Trichoptera	Hydroptilidae		Leucotrichia	36
x	Trichoptera	Hydroptilidae		Ochrotrichia	1
2	Trichoptera	Hydroptilidae		Oxyethira	4
2	Trichoptera	Lepidostomatidae		Lepidostoma	68
2	Trichoptera	Lepidostomatidae		LEPIDOSTOMATIDAE	0
3	Trichoptera	Leptoceridae		Ceraclea	0
x	Trichoptera	Leptoceridae		LEPTOCERIDAE	0
4	Trichoptera	Leptoceridae		Mystacides	2
x	Trichoptera	Leptoceridae		Nectopsyche	0
4	Trichoptera	Leptoceridae		Oecetis	5
4	Trichoptera	Leptoceridae		Triaenodes	7
3	Trichoptera	Apataniidae		Apatania	1
2	Trichoptera	Goeridae		Goera	8
3	Trichoptera	Limnephilidae		Hydatophylax	3
4	Trichoptera	Limnephilidae		Ironoquia	35

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
3	Trichoptera	Limnephilidae		LIMNEPHILIDAE	0
4	Trichoptera	Limnephilidae		Limnephilus	3
3	Trichoptera	Limnephilidae		Platycentropus	0
3	Trichoptera	Limnephilidae		Pycnopsyche	121
3	Trichoptera	Molannidae		Molanna	7
x	Trichoptera	Molannidae		MOLANNIDAE	0
x	Trichoptera	Molannidae		Molannodes	7
x	Trichoptera	NULL		TRICHOPTERA	0
2	Trichoptera	Odontoceridae		ODONTOCERIDAE	0
2	Trichoptera	Odontoceridae		Psilotreta	32
4	Trichoptera	Philopotamidae		Chimarra	1075
3	Trichoptera	Philopotamidae		Dolophilodes	893
x	Trichoptera	Philopotamidae		PHILOPOTAMIDAE	11
2	Trichoptera	Philopotamidae		Wormaldia	42
4	Trichoptera	Phryganeidae		PHRYGANEIDAE	0
4	Trichoptera	Phryganeidae		Ptilostomis	12
x	Trichoptera	Polycentropidae		Cyrnellus	0
x	Trichoptera	Polycentropidae		POLYCENTROPODIDAE	3
4	Trichoptera	Polycentropidae		Polycentropus	195
4	Trichoptera	Polycentropodida		Neureclipsis	5
4	Trichoptera	Polycentropodida		Nyctiophylax	8
2	Trichoptera	Psychomyiidae		Lype	64
3	Trichoptera	Psychomyiidae		Psychomyia	24
3	Trichoptera	Psychomyiidae		PSYCHOMYIIDAE	0
2	Trichoptera	Rhyacophilidae		Rhyacophila	240
x	Trichoptera	Rhyacophilidae		RHYACOPHILIDAE	0
3	Trichoptera	Sericostomatidae		Agarodes	3
x	Trichoptera	Sericostomatidae		SERICOSTOMATIDAE	0
3	Trichoptera	Uenoidae		Neophylax	907
3	Trichoptera	Uenoidae		UENOIDAE	0
x	Tricladida	Dugesiidae		Girardia	167
5	Tricladida	Planariidae		Cura	25
5	Tricladida	Planariidae		Dugesia	0
x	Tricladida	Planariidae		Phagocata	35
5	Tricladida	Planariidae		PLANARIIDAE	1
x	Trombidiformes	Hygrobatidae		Atractides	0
x	Trombidiformes	Hygrobatidae		HYGROBATIDAE	0
x	Trombidiformes	Lebertiidae		Lebertia	2
x	Trombidiformes	Sperchontidae		Sperchon	1
x	Trombidiformes	Hygrobatidae		Hygrobates	0
x	Tubificida	Haplotaxidae		HAPLOTAXIDAE	0
5	Tubificida	Tubificidae		Limnodrilus	86
5	Tubificida	Tubificidae		Spirosperma	284
5	Tubificida	Tubificidae		Tubifex	0
5	Tubificida	Tubificidae		TUBIFICIDAE	77

Table C1. continued…

BCG Attribute	Order	Family	Subfamily	Taxon	# Individs
x	Unionoida	Unionidae		UNIONIDAE	0
x	Veneroida	Corbiculidae		Bivalvia (PELECYPODA)	0
6	Veneroida	Corbiculidae		Corbicula	45
6	Veneroida	Corbiculidae		CORBICULIDAE	0
4	Veneroida	Pisidiidae		PISIDIIDAE	0
4	Veneroida	Sphaeriidae		Musculium	49
4	Veneroida	Sphaeriidae		Pisidium	71
4	Veneroida	Sphaeriidae		SPHAERIDAE	13
4	Veneroida	Sphaeriidae		Sphaerium	44

Appendix D

BCG Attribute Assignments – Fish (Table D1) and Salamanders (Table D2)

Table D1. Maryland Northern Piedmont BCG attribute assignments for fish. This list is sorted by order, family, then by Final Name. # Individs refers to the total number of individuals in the dataset that was used for this project. This list is inclusive of taxa that might occur in the region (but not all of these taxa occur in the project dataset). 'Mid-water cyprinid' is marked as 'yes' if the taxon was included in the mid-water cyprinid metric.

BCG Attribute	Order	Family	Final Name	# Individs	Mid-water cyprinid
10	Anguilliformes	Anguillidae	AMERICAN EEL	9468	
10	Clupeiformes	Clupeidae	GIZZARD SHAD	157	
4	Cypriniformes	Catostomidae	CREEK CHUBSUCKER	152	
6m	Cypriniformes	Catostomidae	GOLDEN REDHORSE	70	
4	Cypriniformes	Catostomidae	SHORTHEAD REDHORSE	1	
5	Cypriniformes	Catostomidae	WHITE SUCKER	19628	
2	Cypriniformes	Catostomidae	NORTHERN HOGSUCKER	2959	
x	Cypriniformes	Cobitidae	ORIENTAL WEATHERFISH	1	
5	Cypriniformes	Cyprinidae	BLACKNOSE DACE	98793	
5	Cypriniformes	Cyprinidae	BLUNTNOSE MINNOW	17908	
1	Cypriniformes	Cyprinidae	BRIDLE SHINER	0	yes
3	Cypriniformes	Cyprinidae	CENTRAL STONEROLLER	11182	
2	Cypriniformes	Cyprinidae	COMELY SHINER	1	yes
6t	Cypriniformes	Cyprinidae	COMMON CARP	46	
3	Cypriniformes	Cyprinidae	COMMON SHINER	8269	yes
5	Cypriniformes	Cyprinidae	CREEK CHUB	24974	
3	Cypriniformes	Cyprinidae	CUTLIP MINNOW	6119	
x	Cypriniformes	Cyprinidae	CYPRINELLA SP.	5	yes
x	Cypriniformes	Cyprinidae	CYPRINID (UNKNOWN)	1	
x	Cypriniformes	Cyprinidae	CYPRINID HYBRID	8	
4	Cypriniformes	Cyprinidae	EASTERN SILVERY MINNOW	193	
3	Cypriniformes	Cyprinidae	FALLFISH	4447	
6t	Cypriniformes	Cyprinidae	FATHEAD MINNOW	446	
5	Cypriniformes	Cyprinidae	GOLDEN SHINER	275	
6t	Cypriniformes	Cyprinidae	GOLDFISH	24	
4	Cypriniformes	Cyprinidae	LONGNOSE DACE	18455	
x	Cypriniformes	Cyprinidae	NOTROPIS SP.	1	yes
2	Cypriniformes	Cyprinidae	RIVER CHUB	5529	
3	Cypriniformes	Cyprinidae	ROSYFACE SHINER	1119	yes
3	Cypriniformes	Cyprinidae	ROSYSIDE DACE	26756	yes
4	Cypriniformes	Cyprinidae	SATINFIN SHINER	2526	yes
4	Cypriniformes	Cyprinidae	SILVERJAW MINNOW	739	yes
4	Cypriniformes	Cyprinidae	SPOTFIN SHINER	2323	yes
3	Cypriniformes	Cyprinidae	SPOTTAIL SHINER	4009	yes

Table D1. continued…

BCG Attribute	Order	Family	Final Name	# Individs	Mid-water cyprinid
4	Cypriniformes	Cyprinidae	SWALLOWTAIL SHINER	6025	
4	Cyprinodontiformes	Fundulidae	BANDED KILLIFISH	363	
5	Cyprinodontiformes	Fundulidae	MUMMICHOG	117	
5	Cyprinodontiformes	Poeciliidae	EASTERN MOSQUITOFISH	1030	
x	Esociformes	Esocidae	REDFIN PICKEREL	33	
5	Esociformes	Umbridae	EASTERN MUDMINNOW	102	
6m	Perciformes	Centrarchidae	BLACK CRAPPIE	14	
6t	Perciformes	Centrarchidae	BLUEGILL	4135	
6t	Perciformes	Centrarchidae	GREEN SUNFISH	3992	
x	Perciformes	Centrarchidae	HYBRID SUNFISH	3	
6t	Perciformes	Centrarchidae	LARGEMOUTH BASS	1254	
x	Perciformes	Centrarchidae	LEPOMIS HYBRID	51	
6m	Perciformes	Centrarchidae	LONGEAR SUNFISH	304	
4	Perciformes	Centrarchidae	PUMPKINSEED	1408	
5	Perciformes	Centrarchidae	REDBREAST SUNFISH	4617	
6m	Perciformes	Centrarchidae	ROCK BASS	522	
6m	Perciformes	Centrarchidae	SMALLMOUTH BASS	1245	
x	Perciformes	Centrarchidae	SUNFISH (HYBRID)	4	
x	Perciformes	Centrarchidae	SUNFISH (UNKNOWN)	9	
6m	Perciformes	Centrarchidae	white crappie	0	
x	Perciformes	Moronidae	STRIPED BASS	8	
x	Perciformes	Moronidae	WHITE PERCH	5	
4	Perciformes	Percidae	FANTAIL DARTER	6042	
3	Perciformes	Percidae	GREENSIDE DARTER	1751	
x	Perciformes	Percidae	RAINBOW DARTER	100	
2	Perciformes	Percidae	SHIELD DARTER	3	
4	Perciformes	Percidae	TESSELLATED DARTER	17131	
x	Perciformes	Percidae	WALLEYE	2	
2	Perciformes	Percidae	YELLOW PERCH	63	
2	Perciformes	Centrarchidae	WARMOUTH	0	
x	Perciformes	Percidae	BANDED DARTER	40	
1	Perciformes	Percidae	CHESAPEAKE LOGPERCH	0	
1	Perciformes	Percidae	MARYLAND DARTER	0	
1	Percopsiformes	Percopsidae	TROUT PERCH	0	
4	Petromyzontiformes	Petromyzontidae	LEAST BROOK LAMPREY	50	
10	Petromyzontiformes	Petromyzontidae	SEA LAMPREY	731	

Table D1. continued…

BCG Attribute	Order	Family	Final Name	# Individs	Mid-water cyprinid
1	Salmoniformes	Salmonidae	BROOK TROUT	27	
6i	Salmoniformes	Salmonidae	BROWN TROUT	2446	
6i	Salmoniformes	Salmonidae	RAINBOW TROUT	41	
3	Scorpaeniformes	Cottidae	BLUE RIDGE SCULPIN	55596	
3	Scorpaeniformes	Cottidae	POTOMAC SCULPIN	6592	
5	Siluriformes	Ictaluridae	BROWN BULLHEAD	178	
6t	Siluriformes	Ictaluridae	CHANNEL CATFISH	25	
2	Siluriformes	Ictaluridae	MARGINED MADTOM	2334	
5	Siluriformes	Ictaluridae	YELLOW BULLHEAD	1197	

Table D2. Maryland Northern Piedmont BCG attribute assignments for salamanders. Only stream-dwelling species were assigned.

BCG Attribute	Final Name
x	EASTERN RED SPOTTED NEWT
x	EASTERN RED-BACKED SALAMANDER
x	JEFFERSON SALAMANDER
2	LONG-TAILED SALAMANDER
x	MARBLED SALAMANDER
2	NORTHERN DUSKY SALAMANDER
2	NORTHERN RED SALAMANDER
x	NORTHERN SLIMY SALAMANDER
4	NORTHERN TWO-LINED SALAMANDER
x	SALAMANDER UNKNOWN
x	SPOTTED SALAMANDER

Appendix E

Macroinvertebrate Capture Probability Modeled vs. Disturbance Gradient

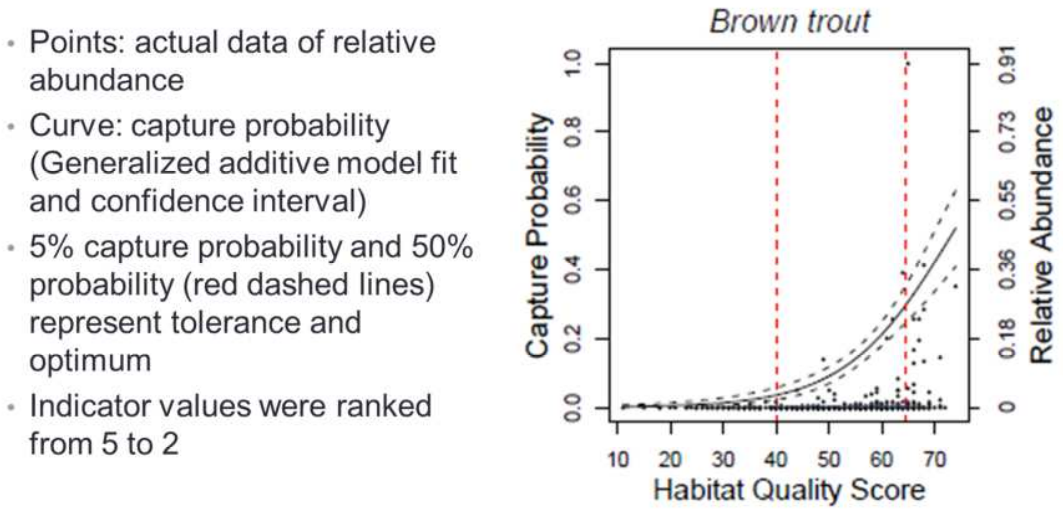
Statistical approaches to determine indicator values (by Lei Zheng, Tetra Tech)

As described in Yuan's (2006) review of approaches for developing indicator values of biological community to various environmental stressors, four different statistical approaches could be applied: (1) central tendencies, (2) environmental limits, (3) optima, and (4) curve shapes. Tolerance values expressed in terms of central tendencies attempt to describe the average environmental conditions under which a species is likely to occur; indicator values expressed in terms of environmental limits attempt to capture the maximum or the minimum level of an environmental variable under which a species can persist; and indicator values expressed in terms of optima define the environmental conditions that are most preferred by a given species. These types of indicator values are expressed in terms of locations on a continuous numerical scale that represents the environmental gradient of interest. Both abundance-based and presence/absence-based models can be built using these statistical approaches.

The tolerance analyses for this project are based on MBSS Piedmont data (excluding limestone streams). The dataset consisted of 603 samples. Analyses were performed for the following 2 stressor variables: imperviousness and habitat score. Three groups of models were used in the analyses:

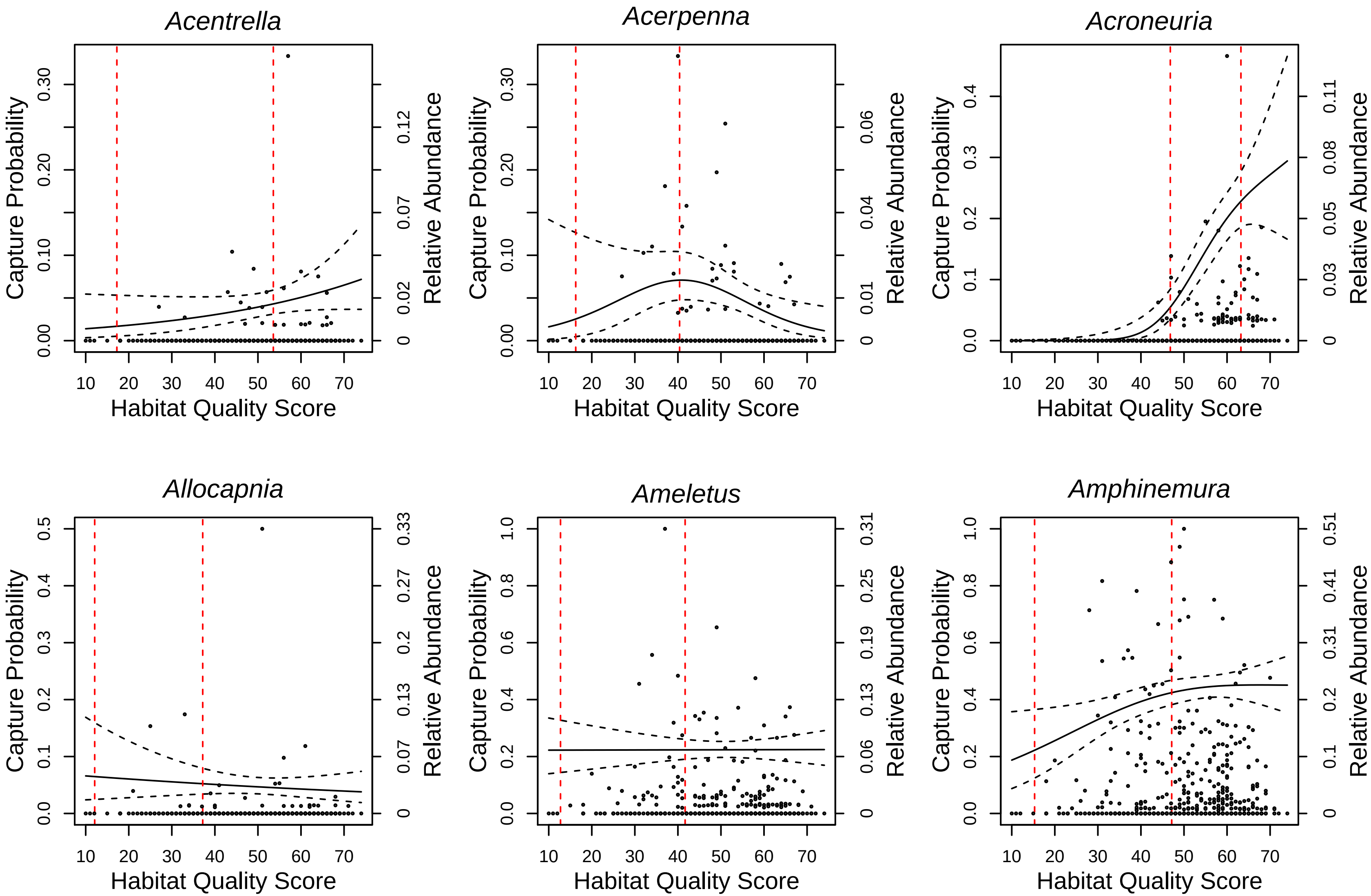
- Weighted averaging to estimate optima and tolerance values (abundance based)
- Cumulative distribution function median and extreme limits (presence/absence)
- Logistic regression (linear, nonlinear, generalized additive model) median and extreme limits (presence/absence)

Taxon-response plots like the example shown below were generated for the taxa in the dataset. These were used to help inform BCG attribute assignments at the September 2013 workshop.

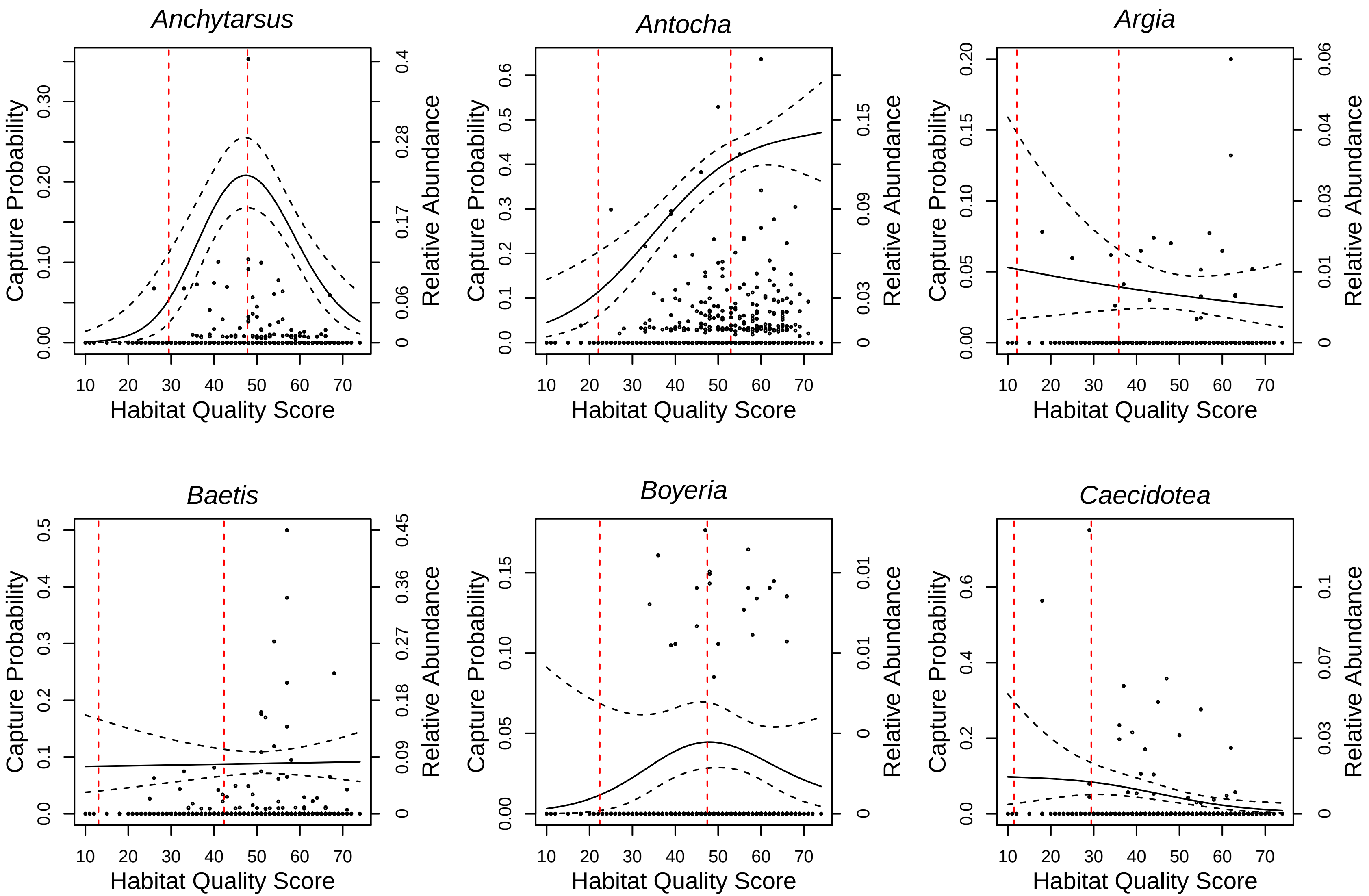


RESPONSES OF MACROINVERTEBRATE TAXA TO HABITAT QUALITY

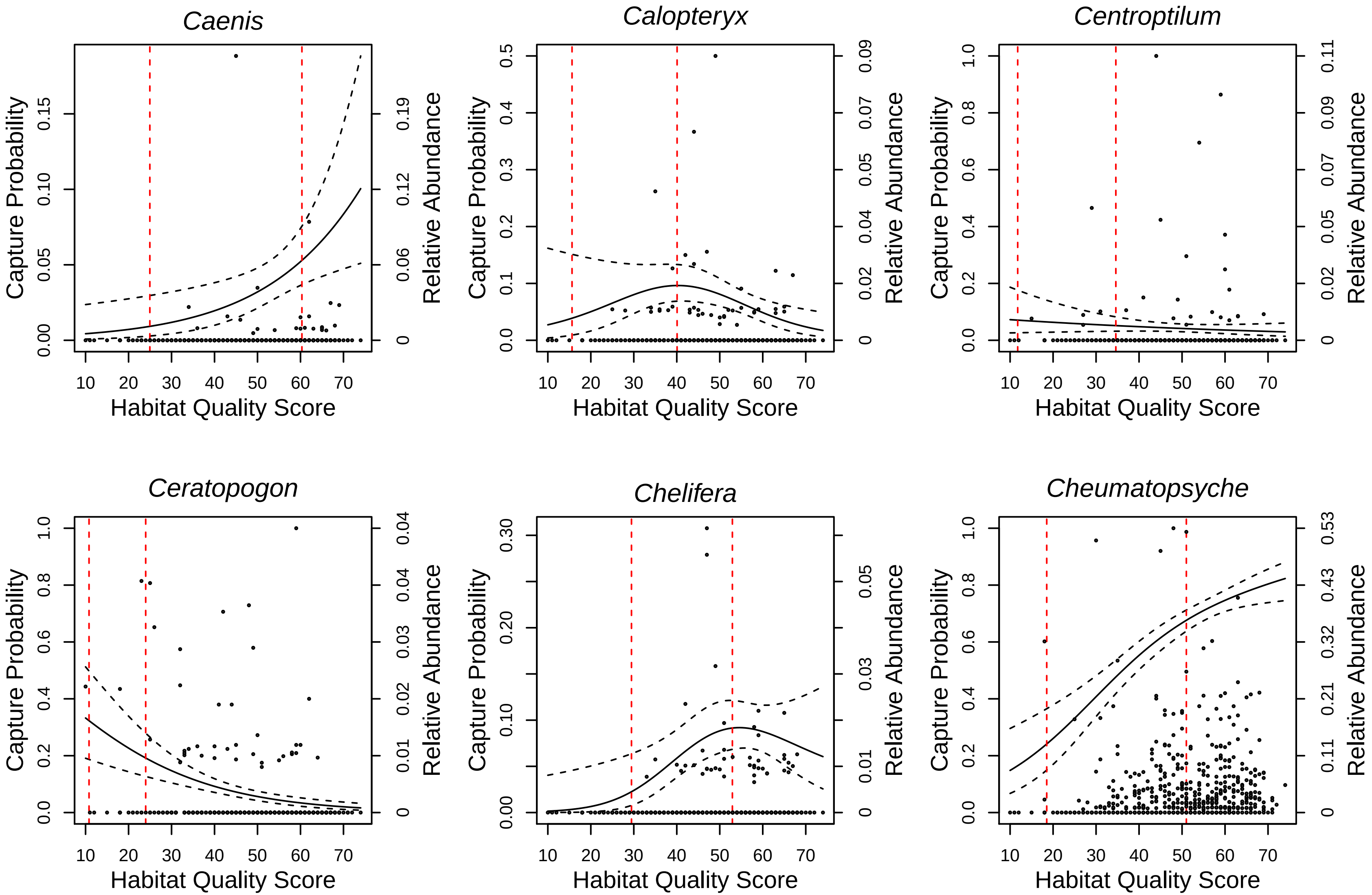
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



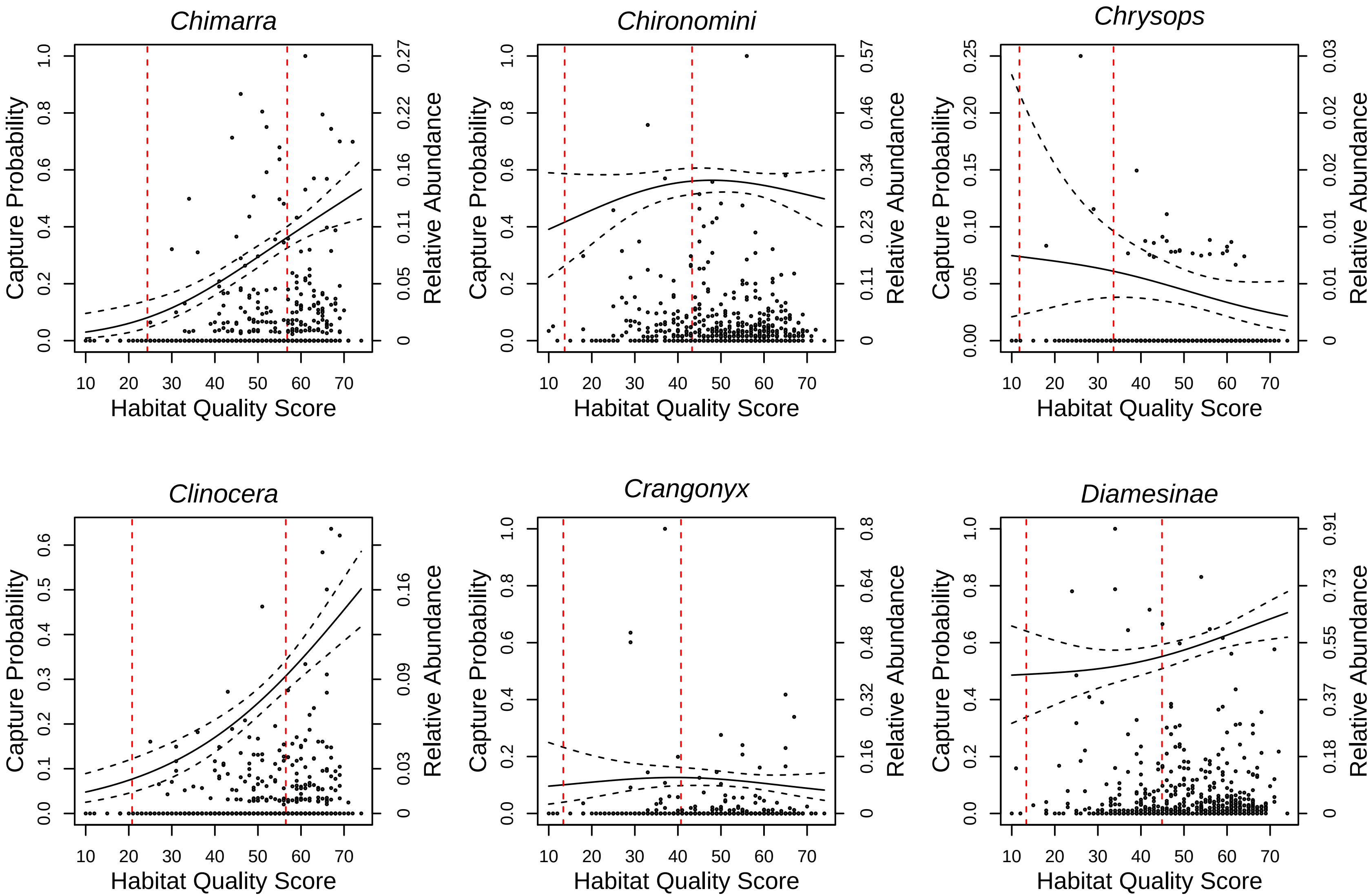
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



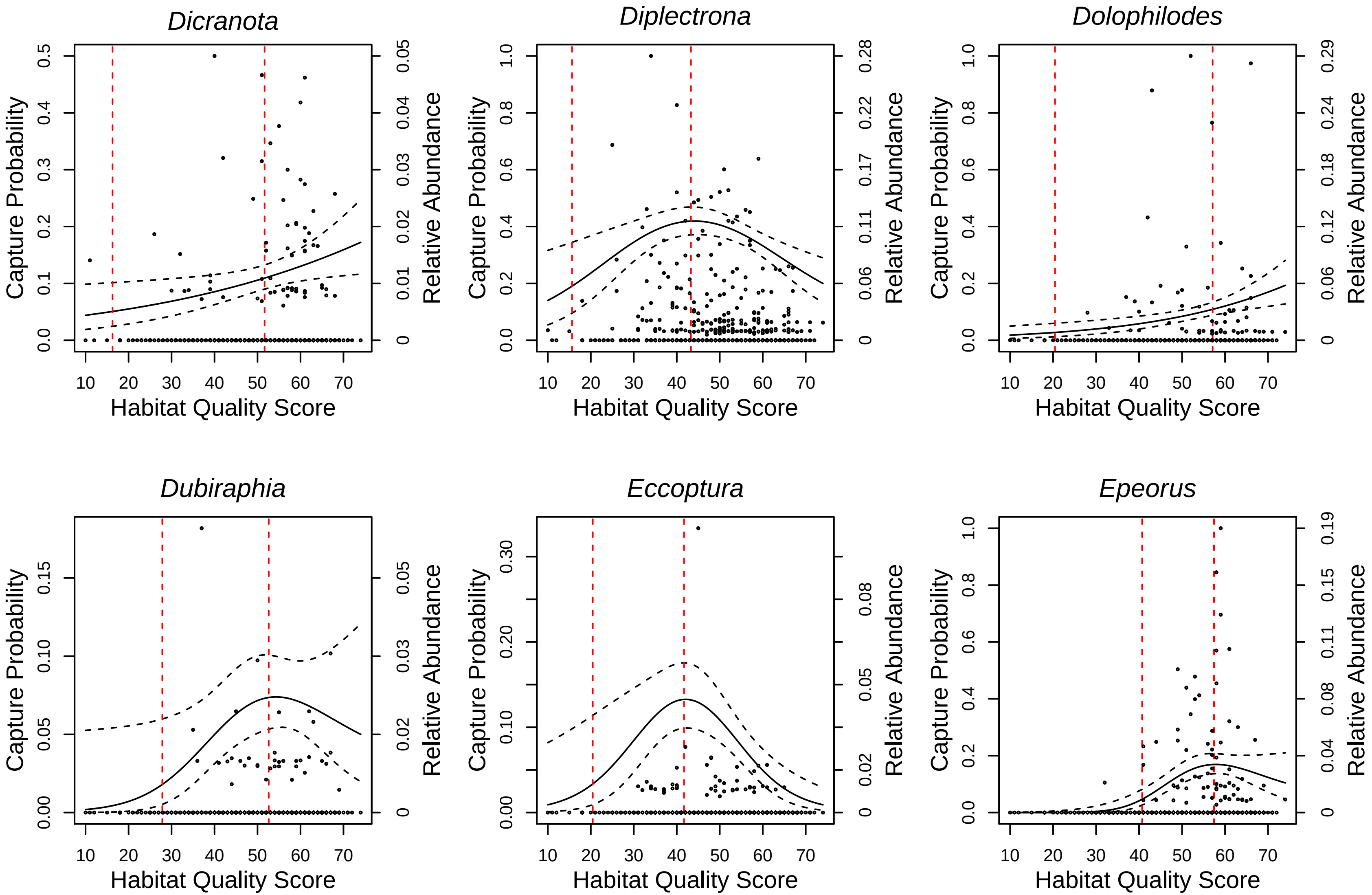
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



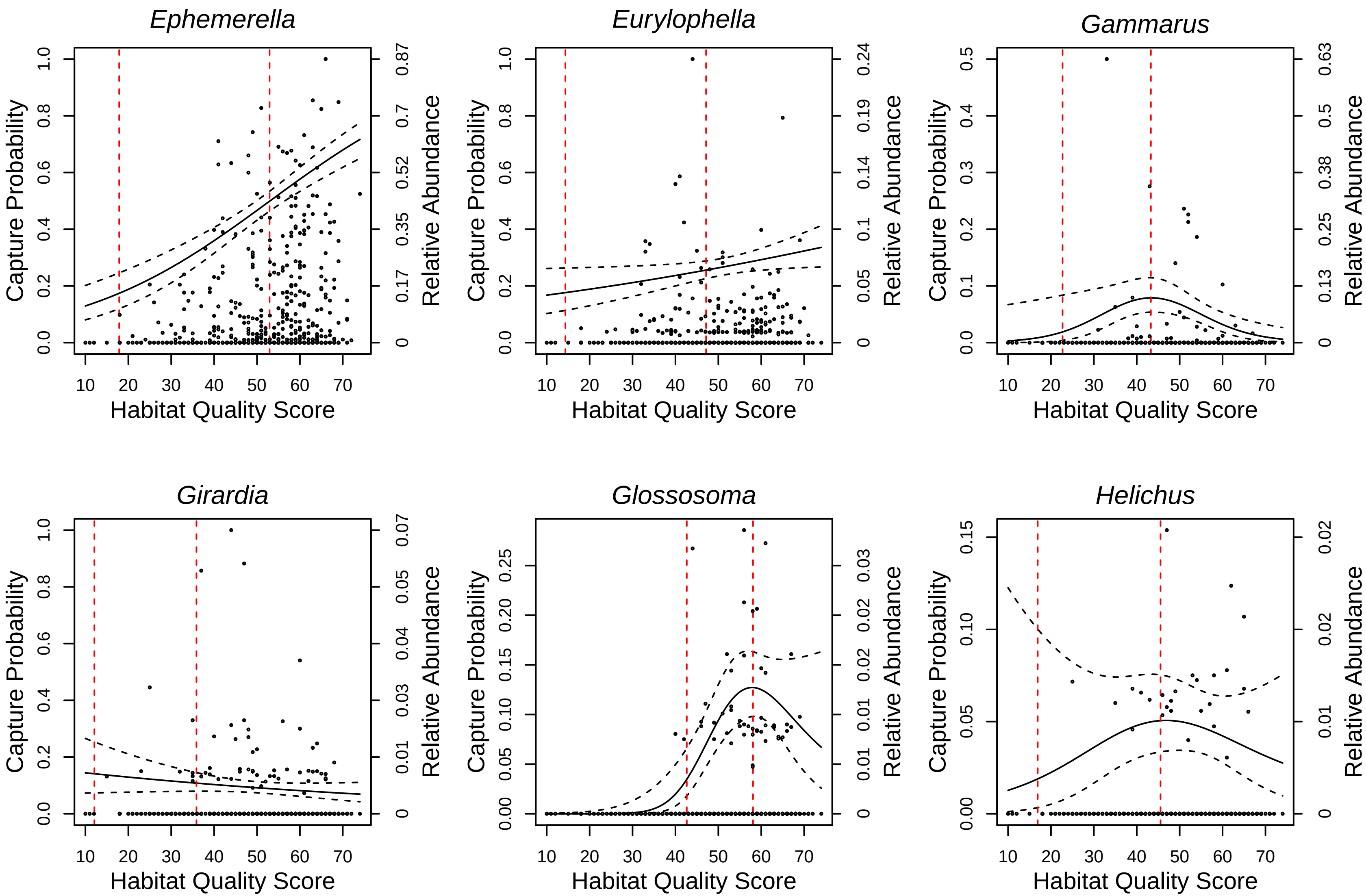
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



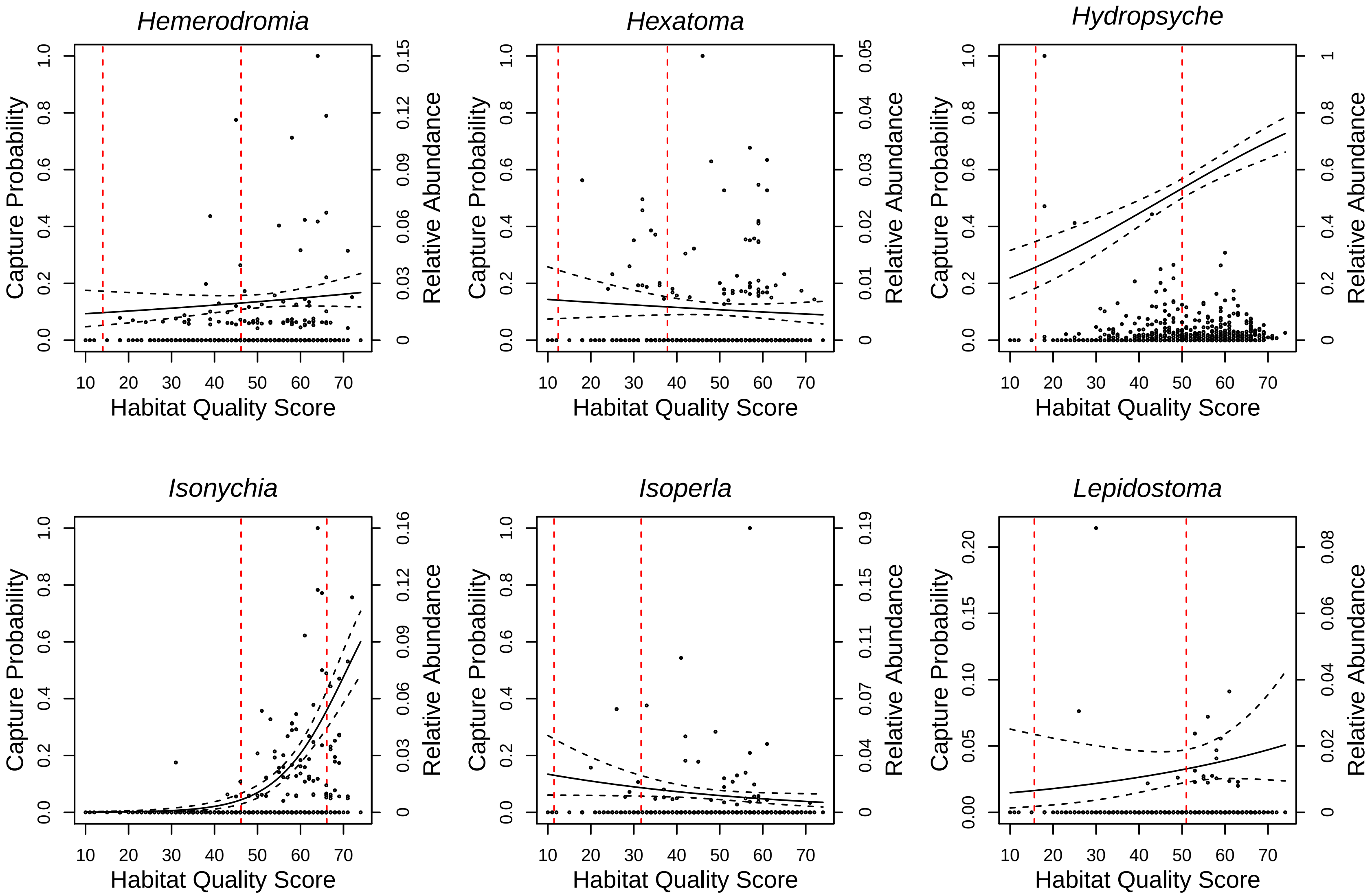
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



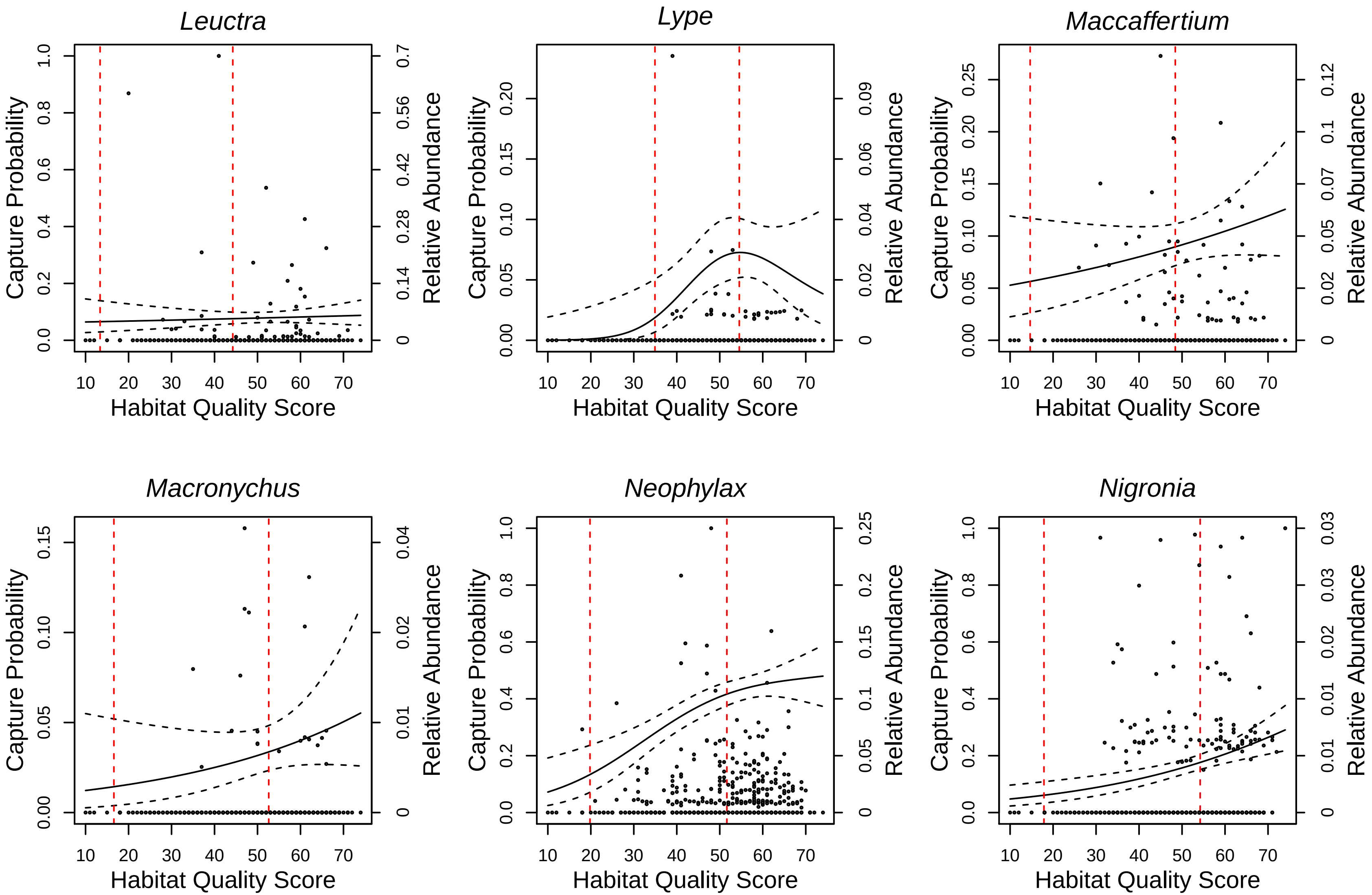
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



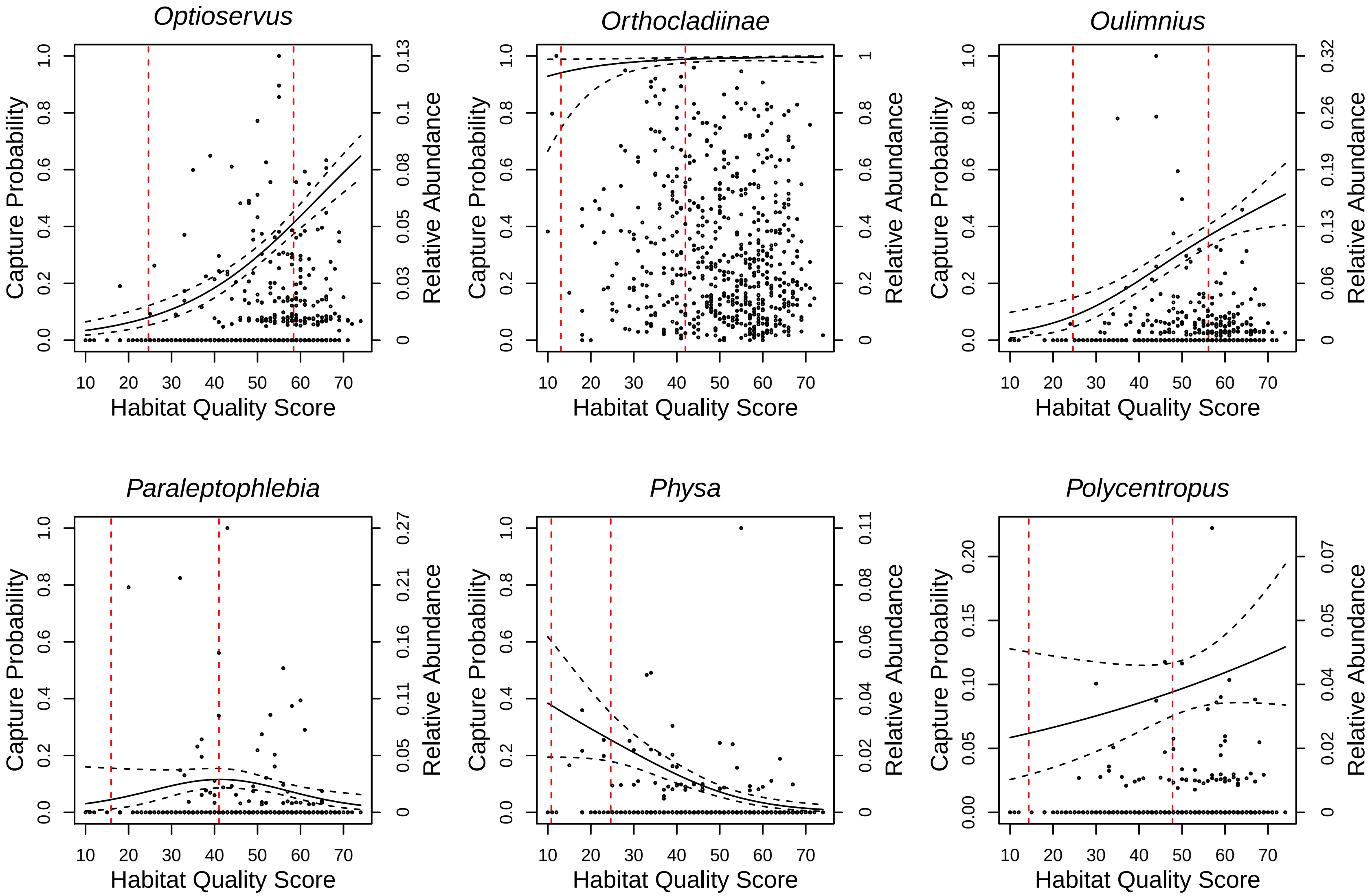
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



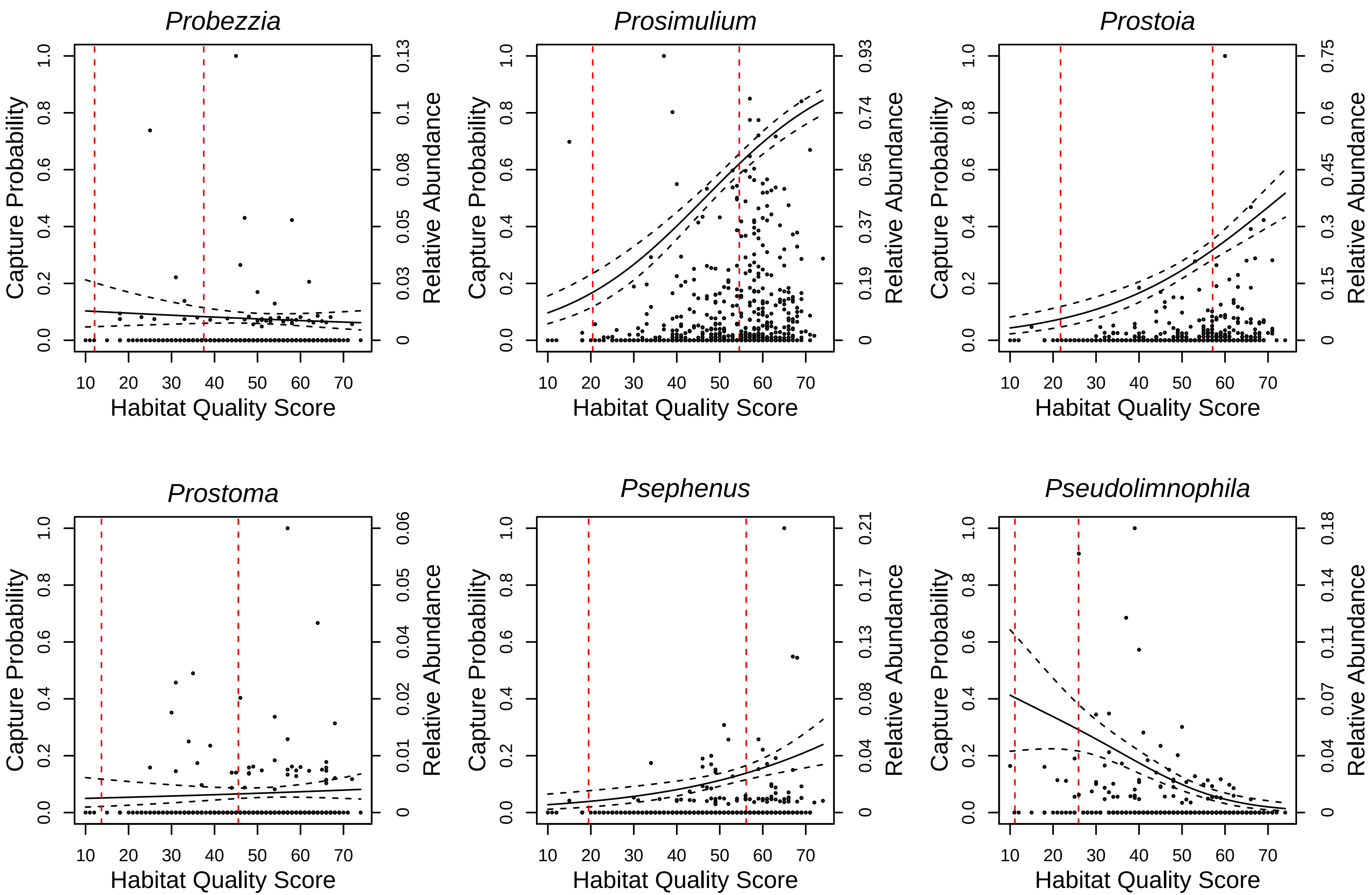
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient

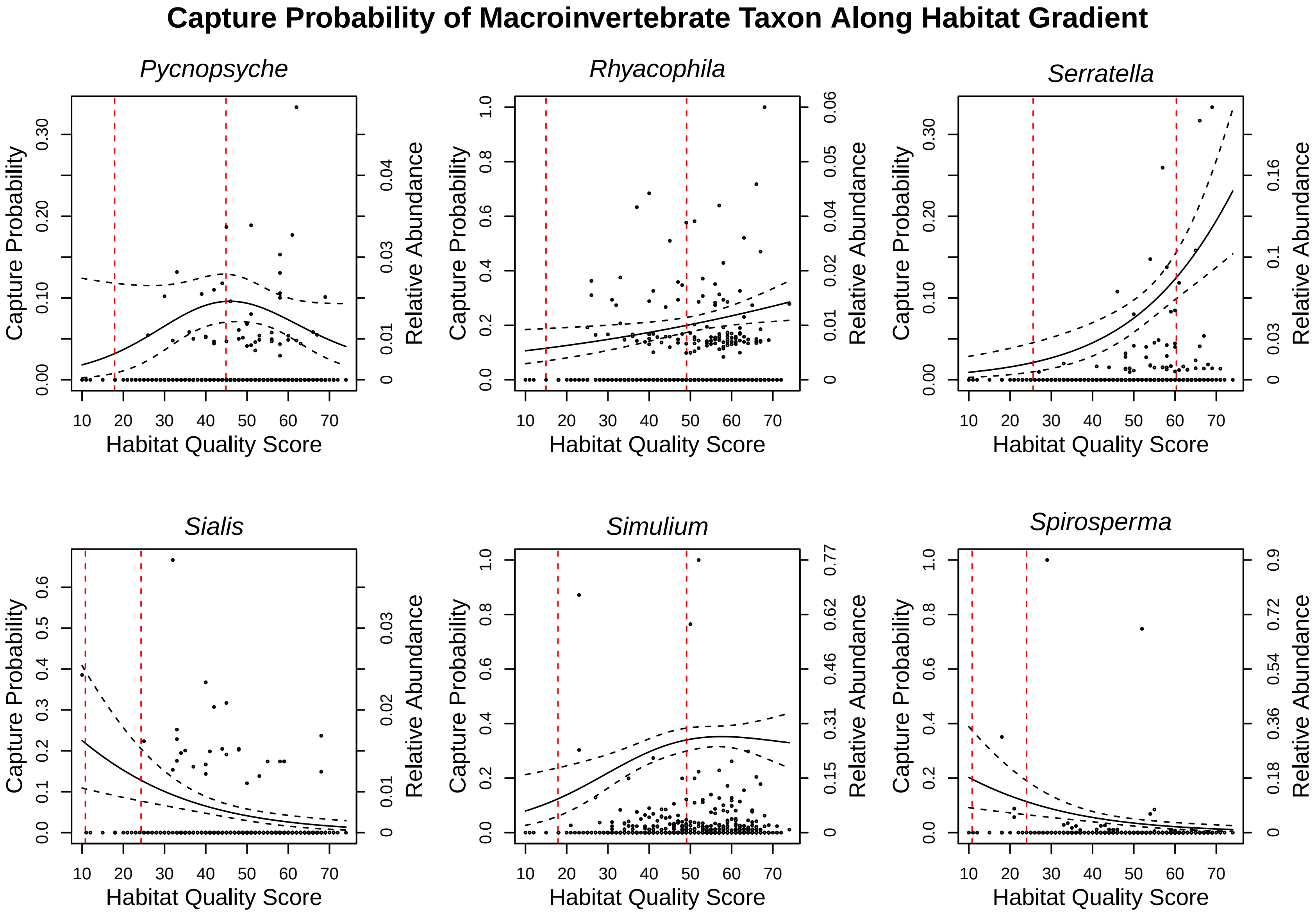


Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



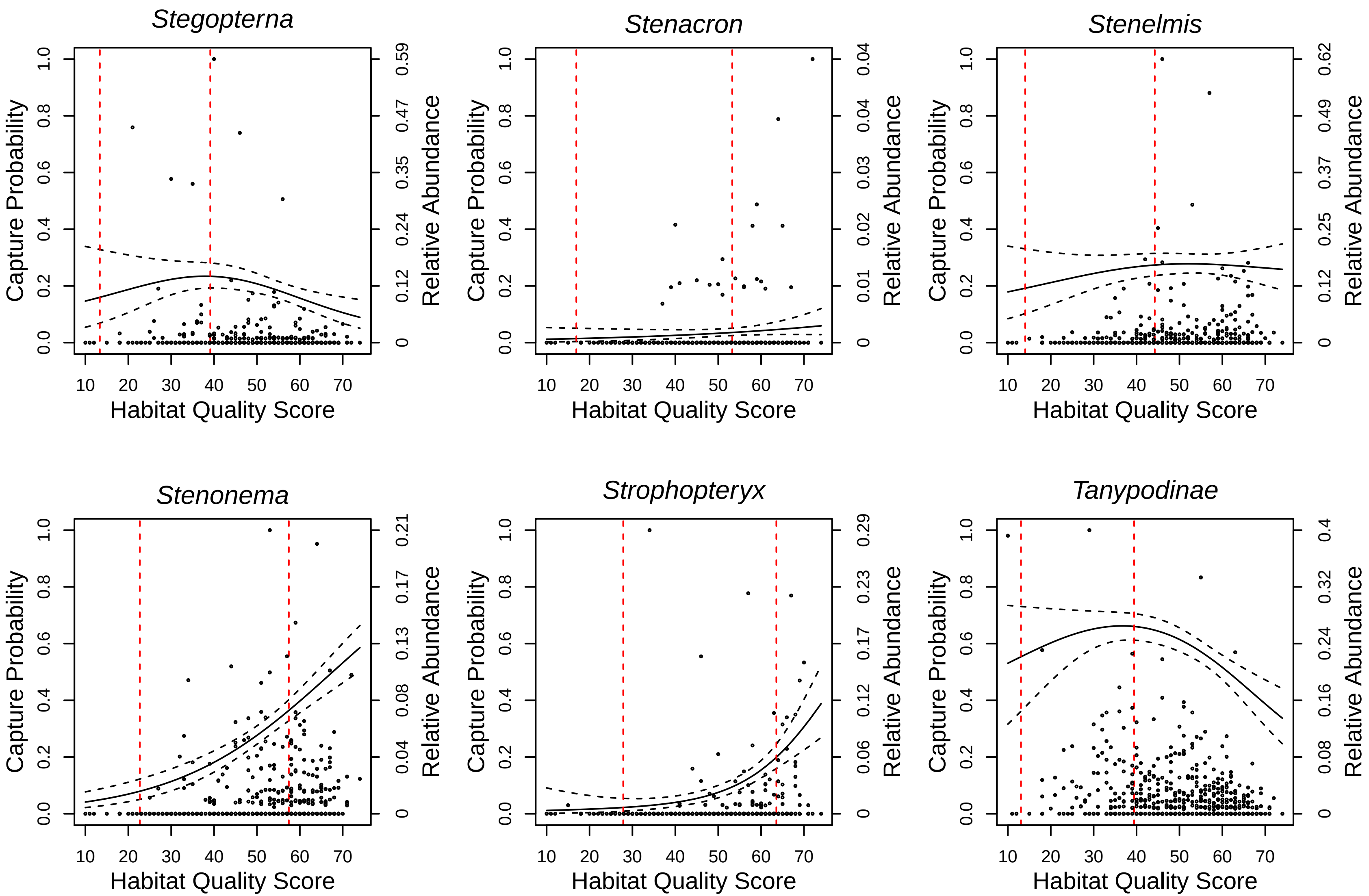
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



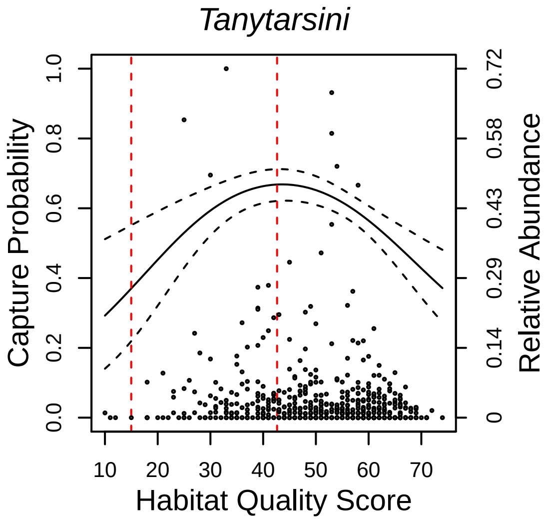


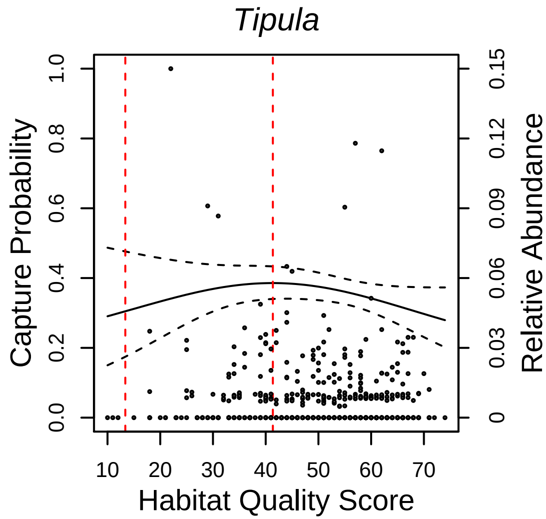
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient
Pycnopsyche
Rhyacophila
Serratella
Sialis
Simulium
Spirosperma
Capture Probability
Relative Abundance
Habitat Quality Score

Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



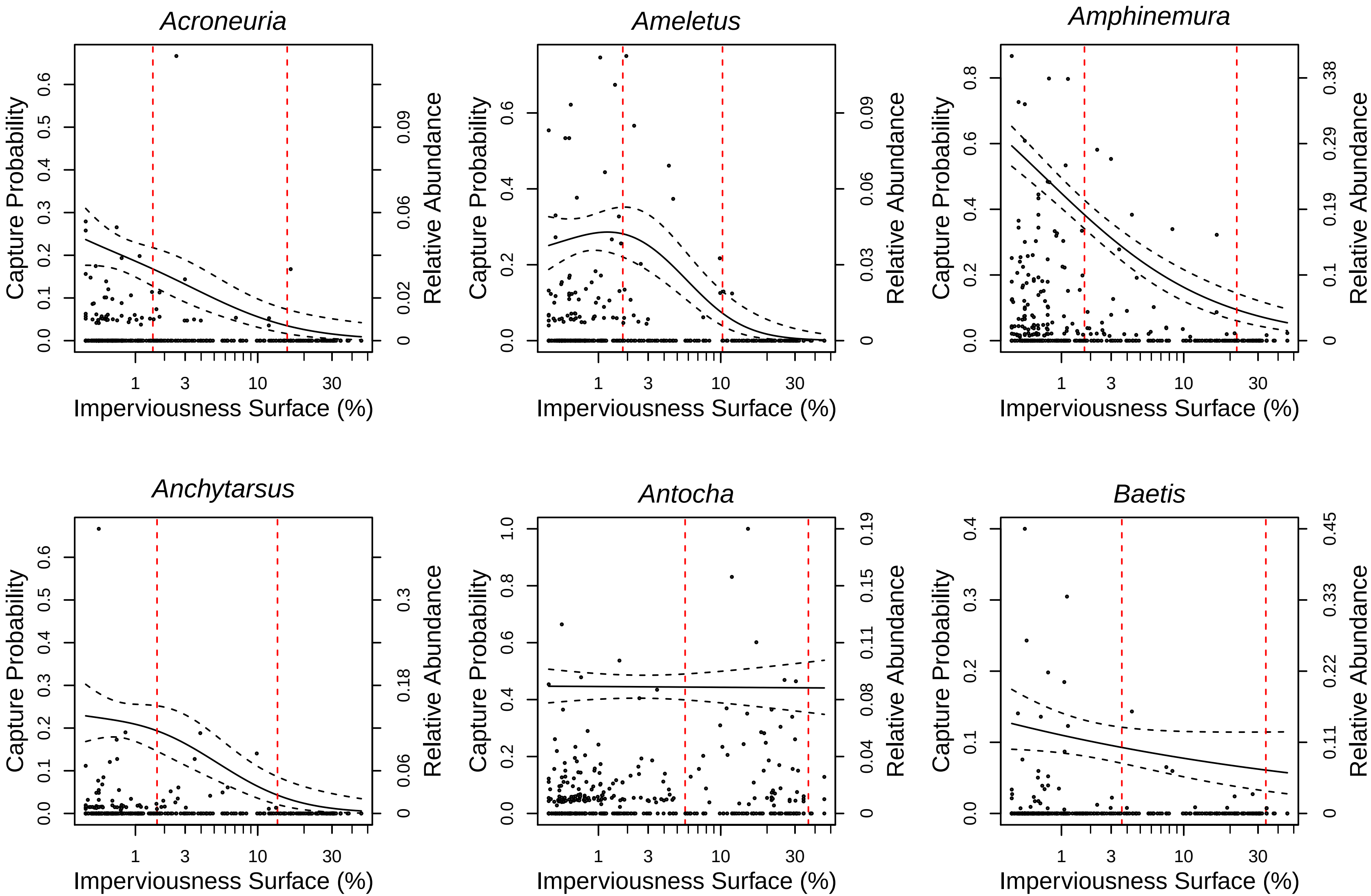
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



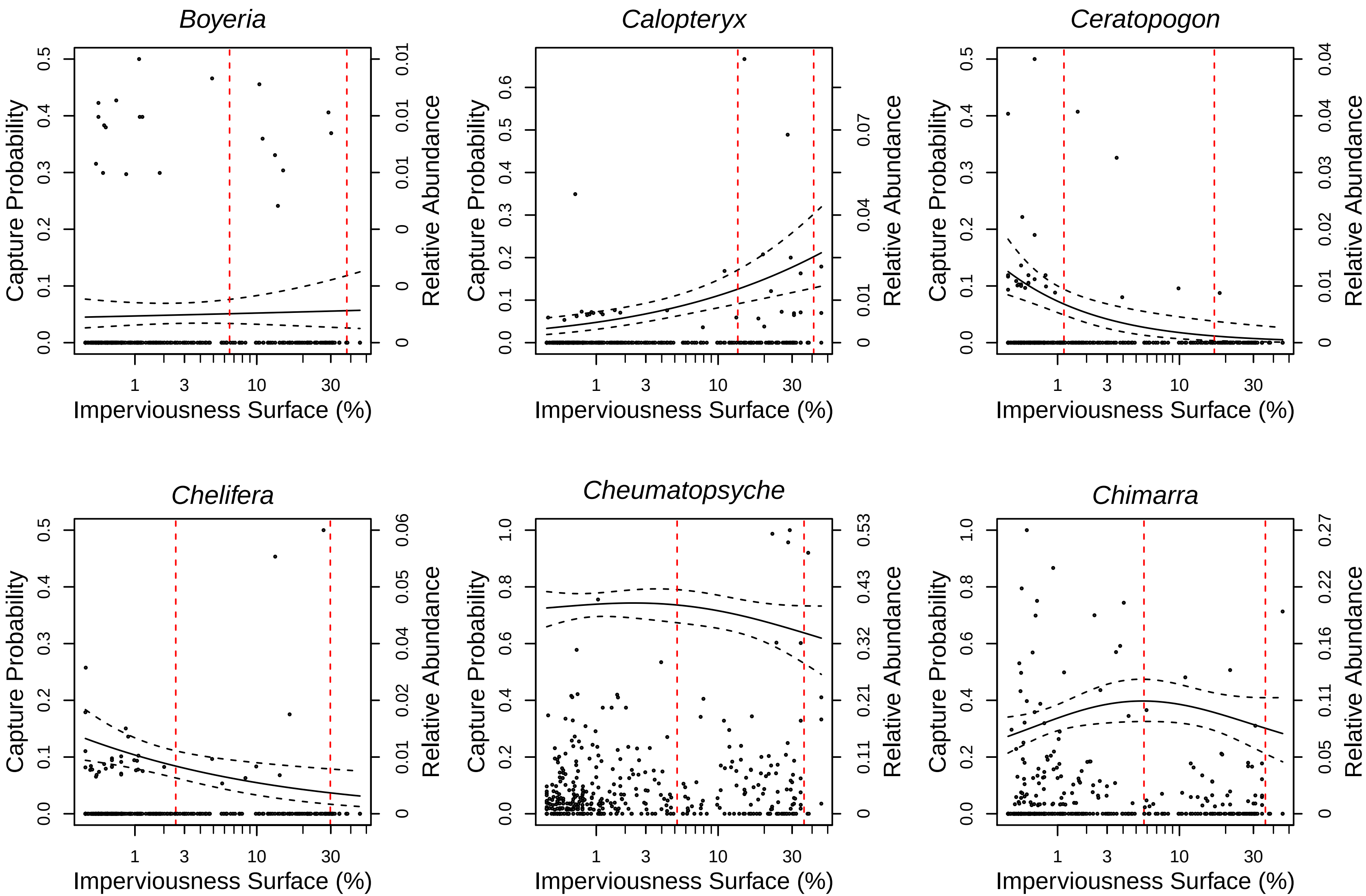


RESPONSES OF MACROINVERTEBRATE TAXA TO % IMPERVIOUS SURFACE

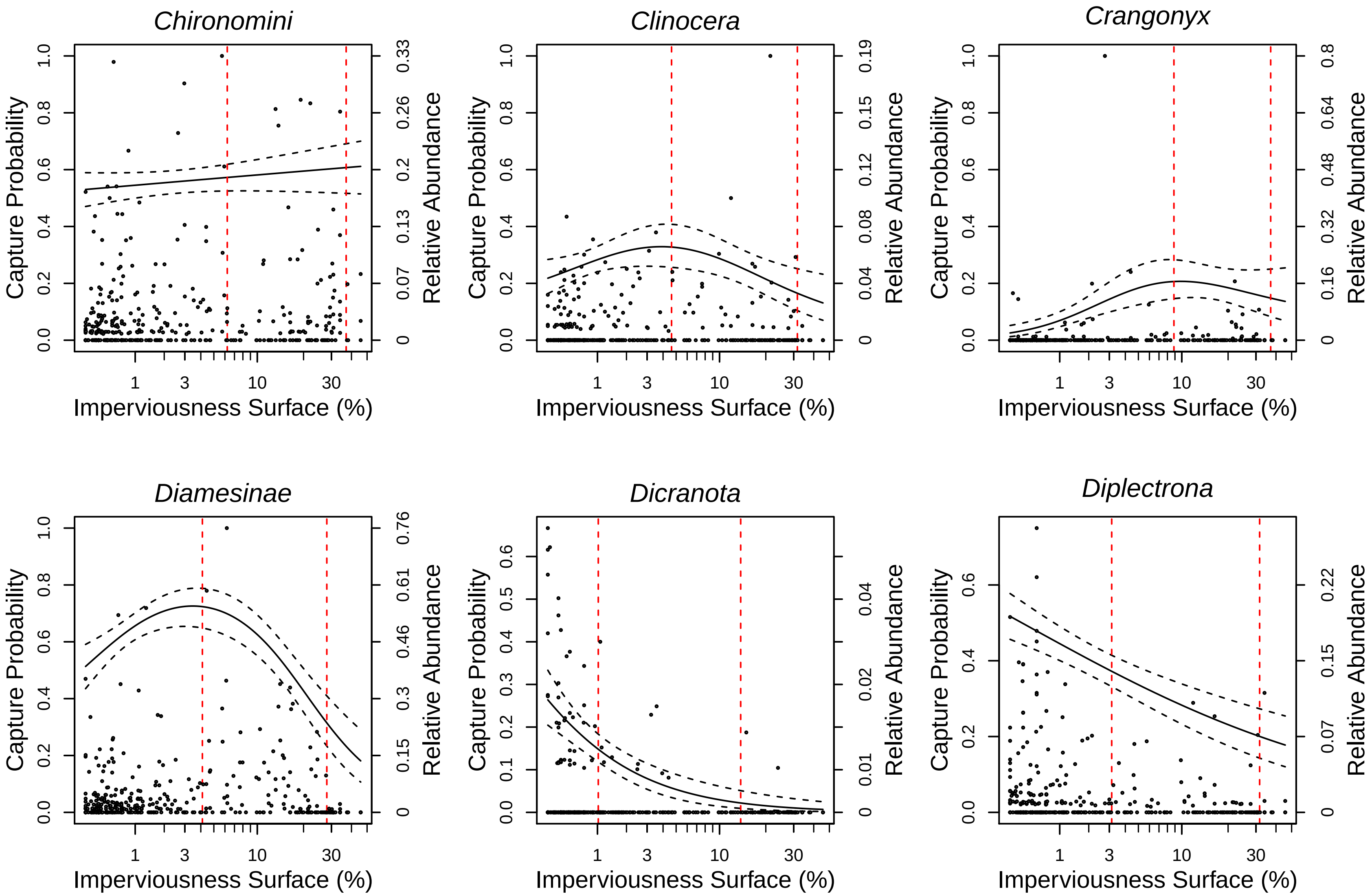
Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



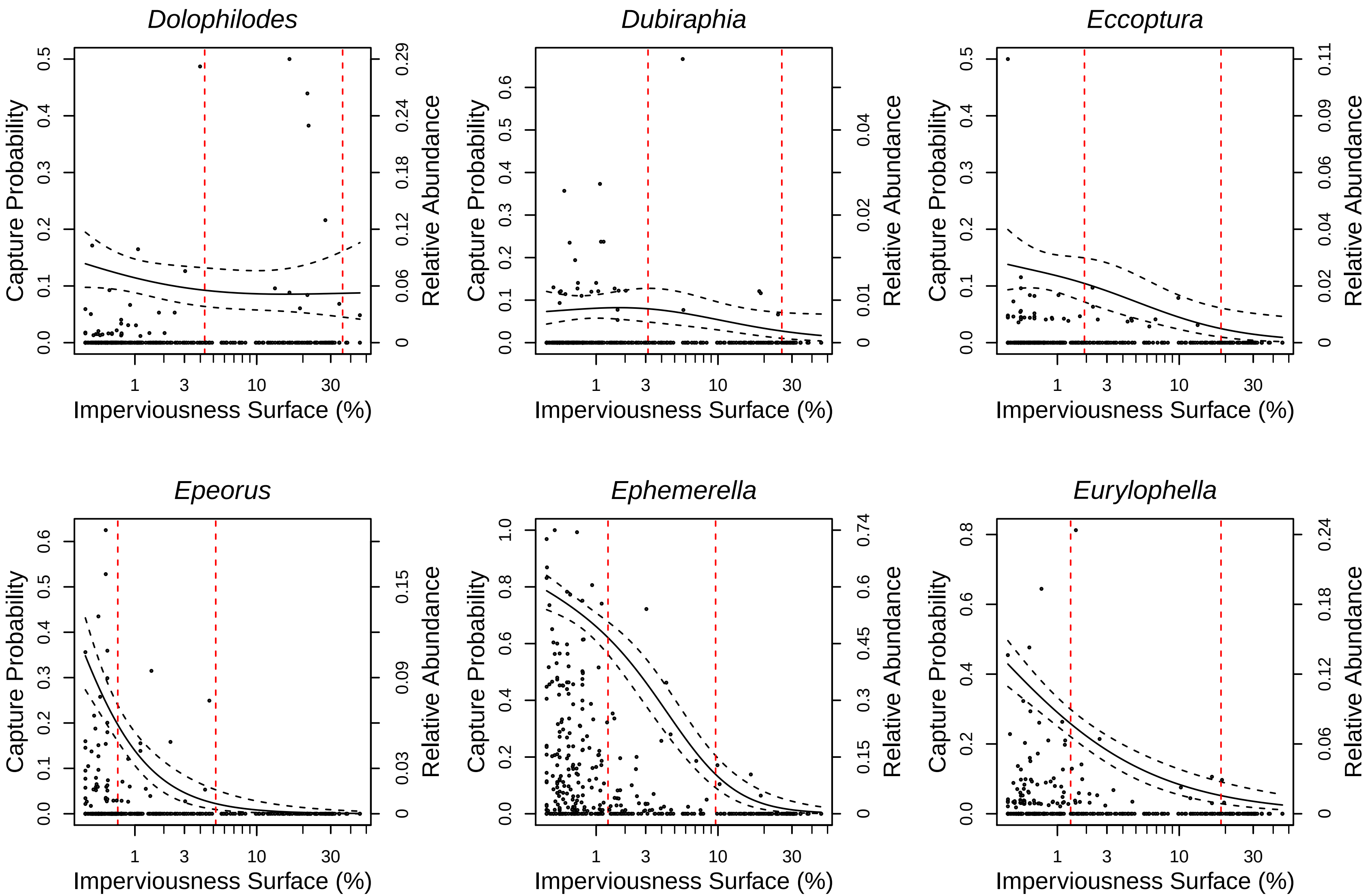
Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



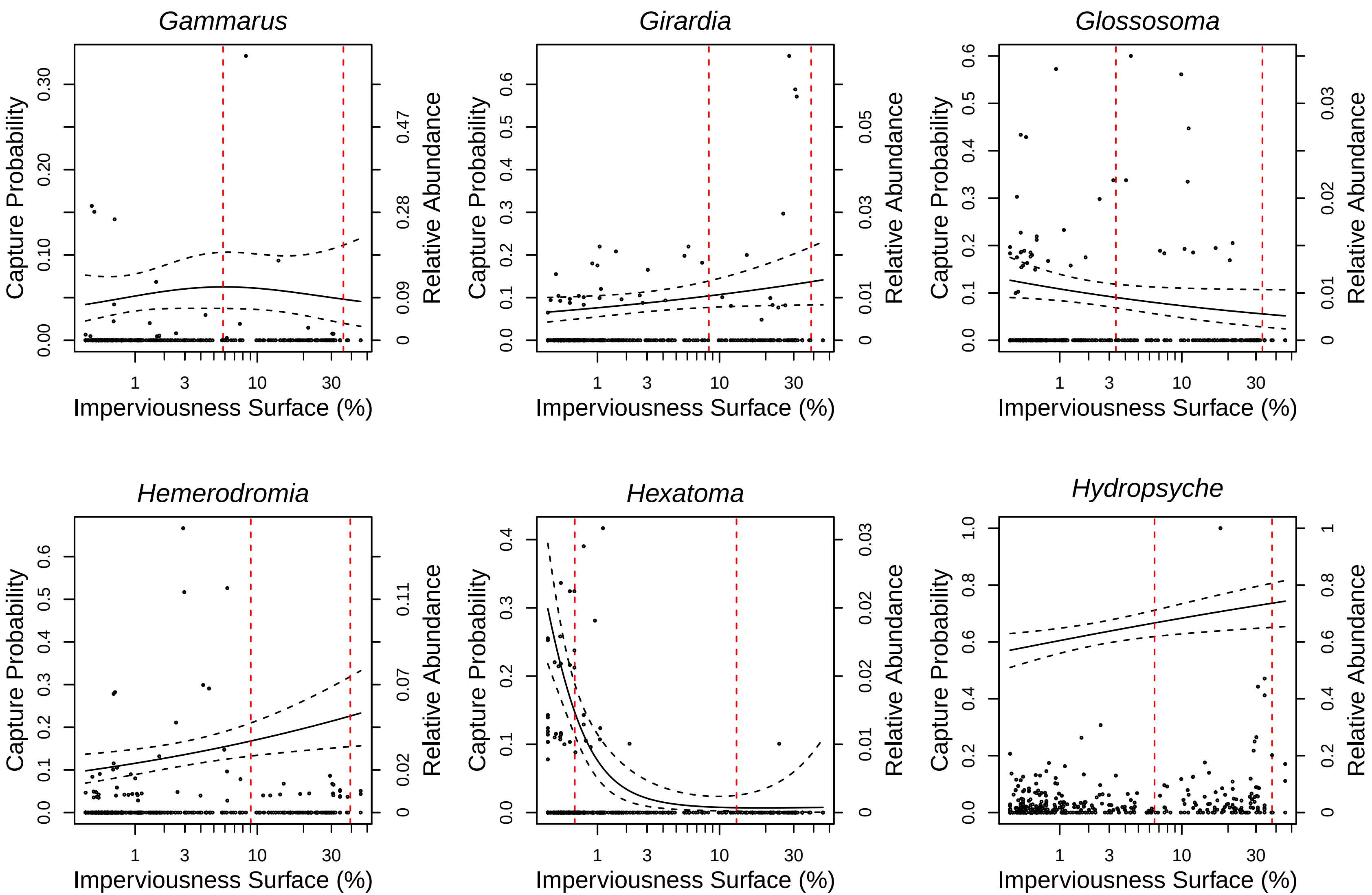
Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



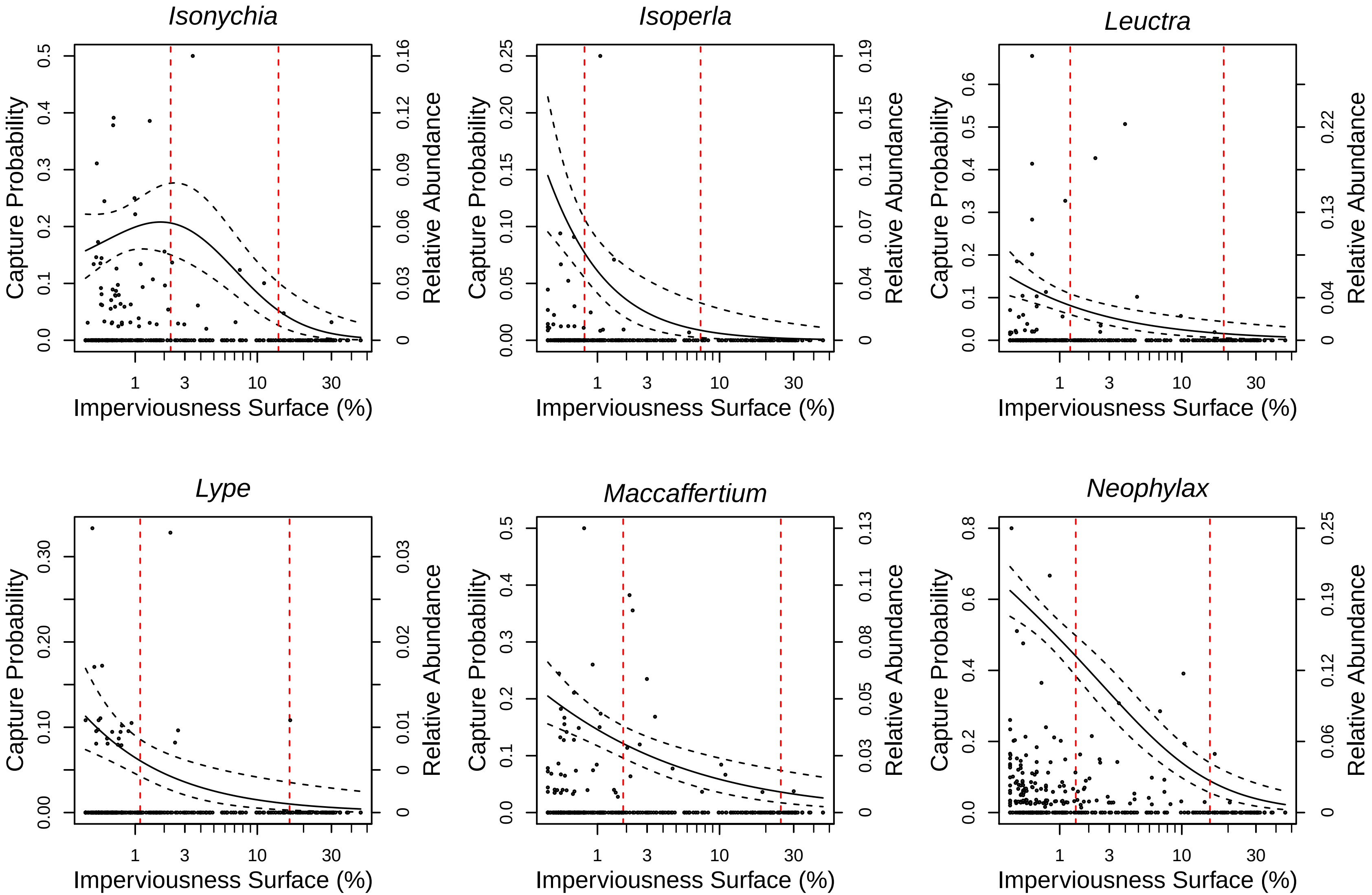
Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



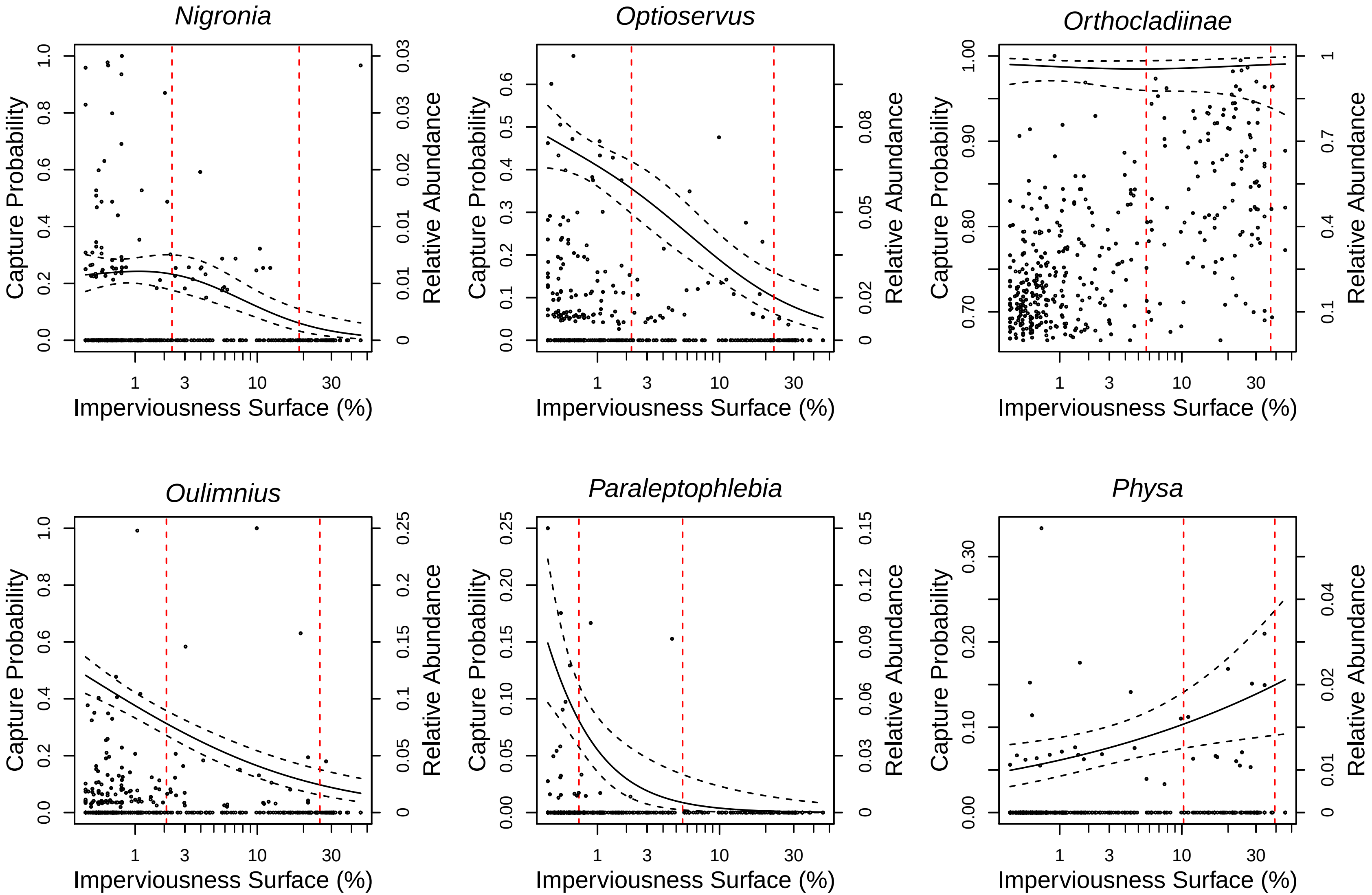
Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



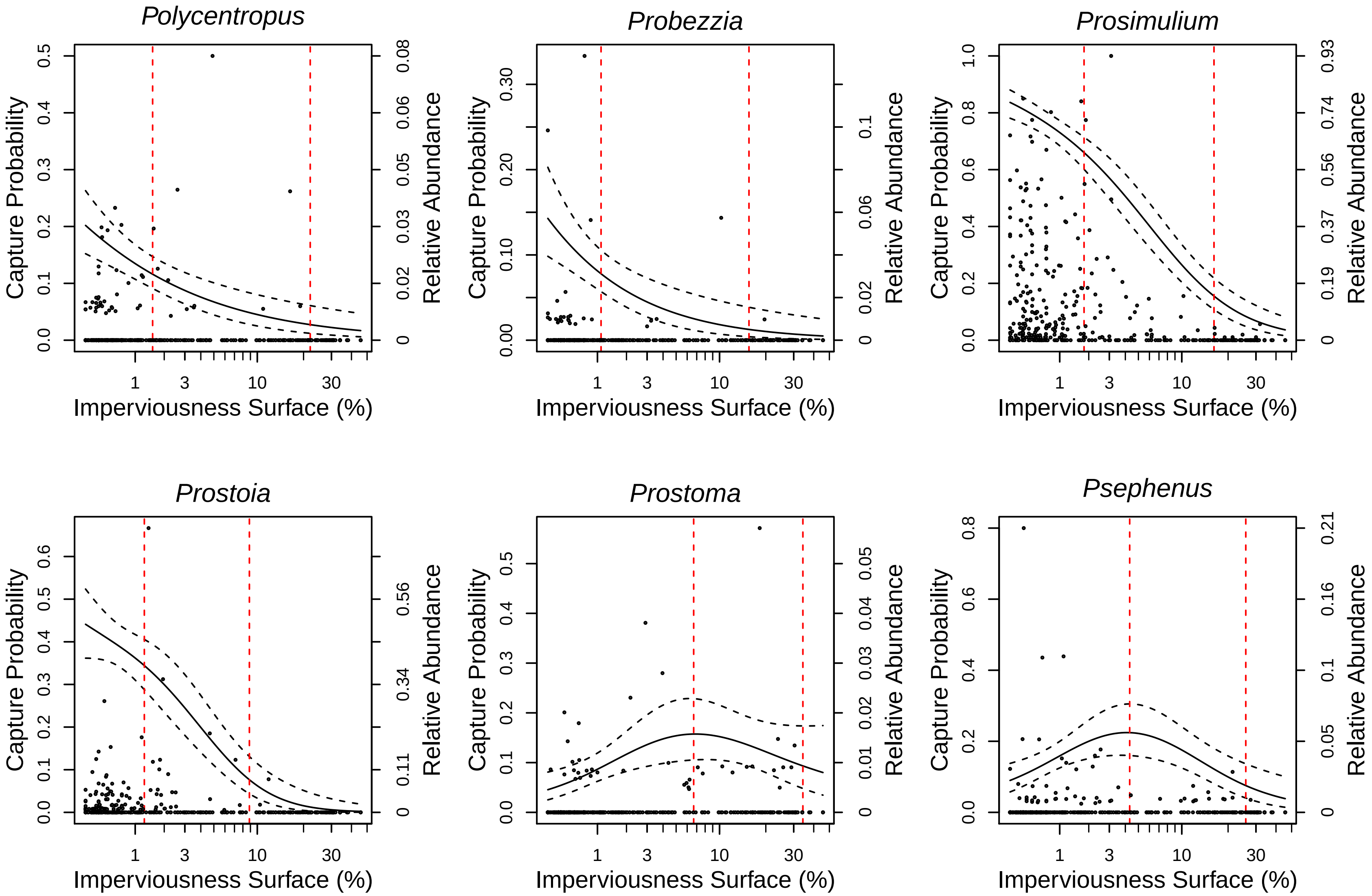
Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



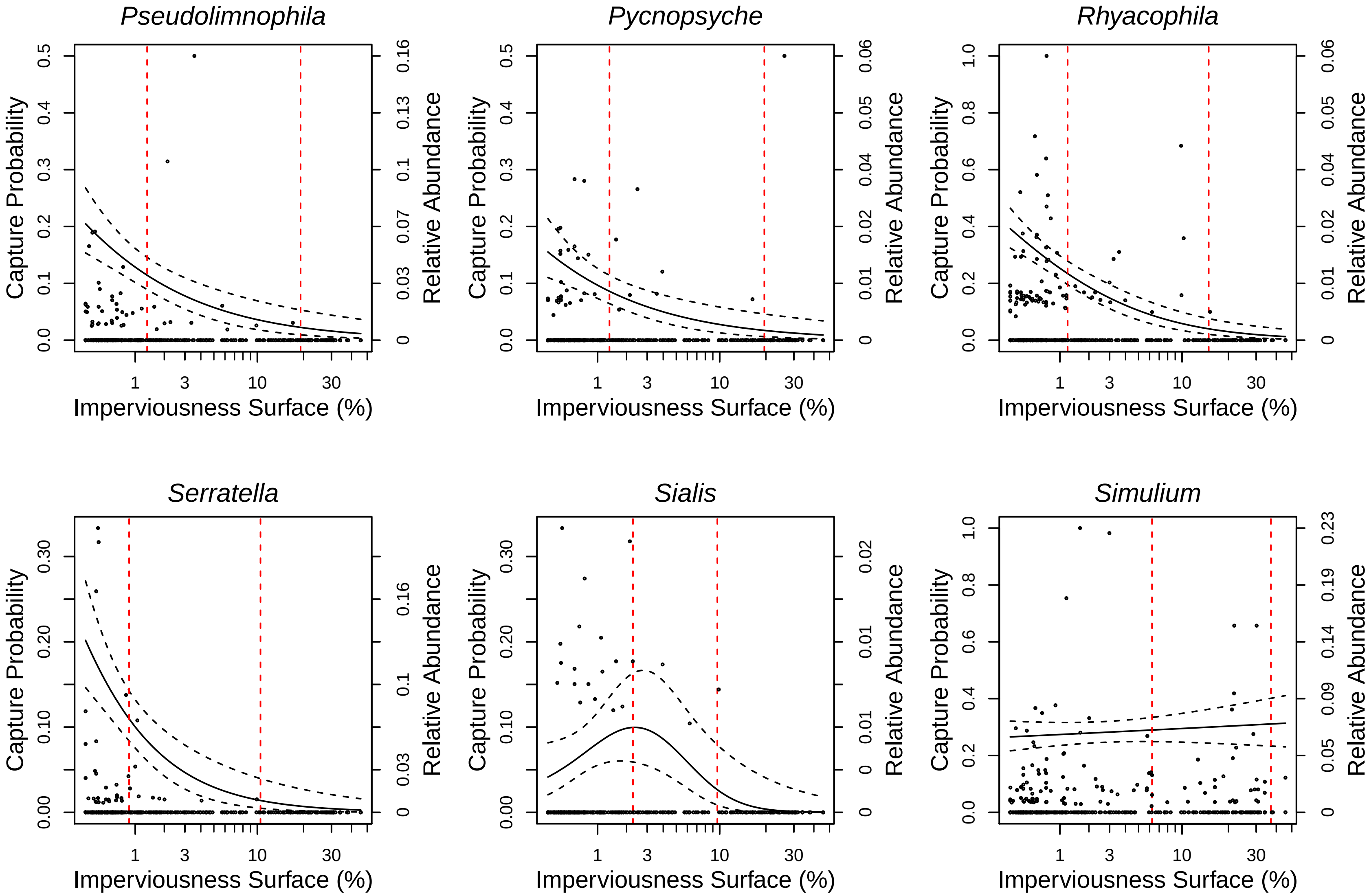
Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



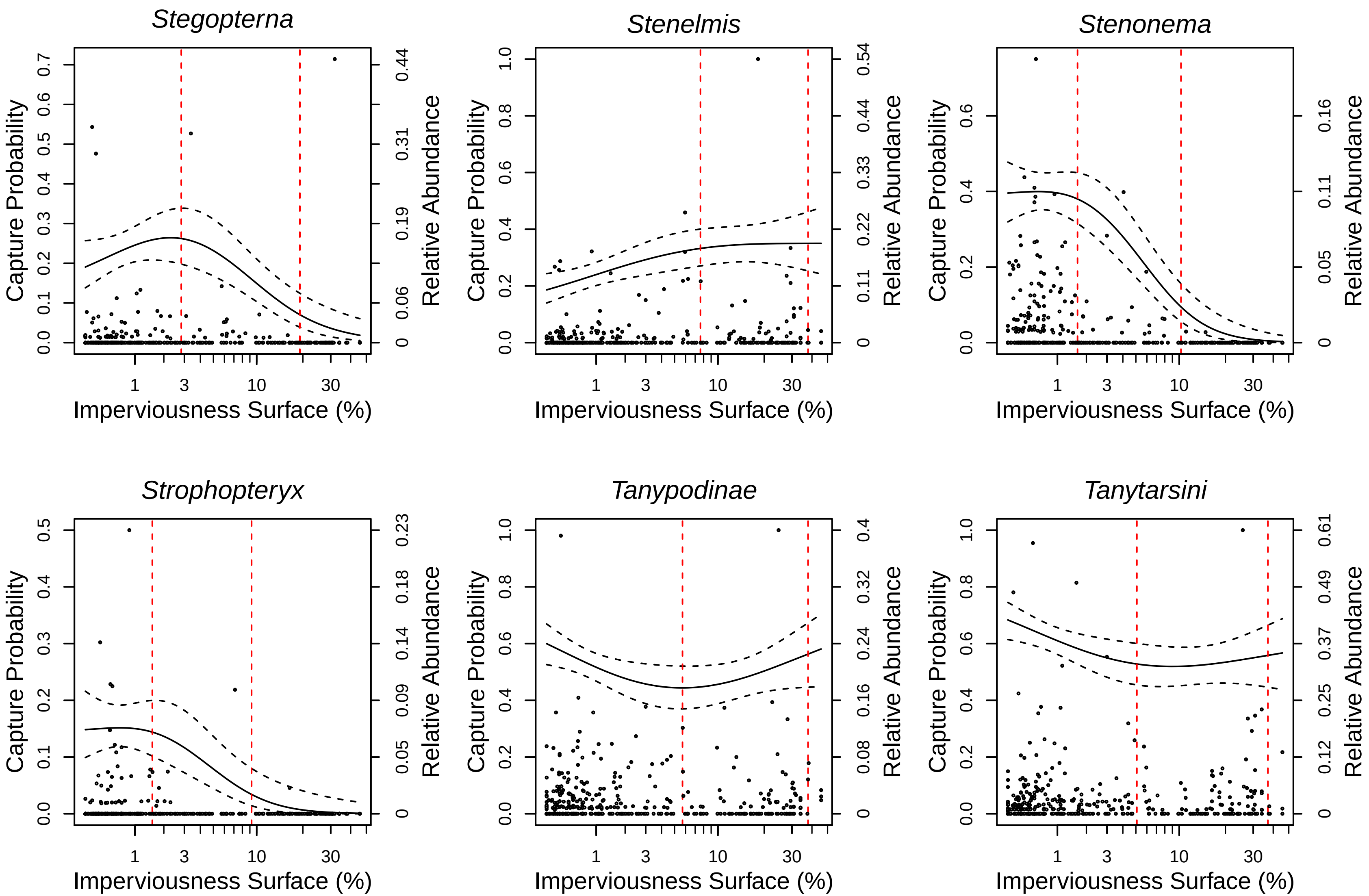
Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



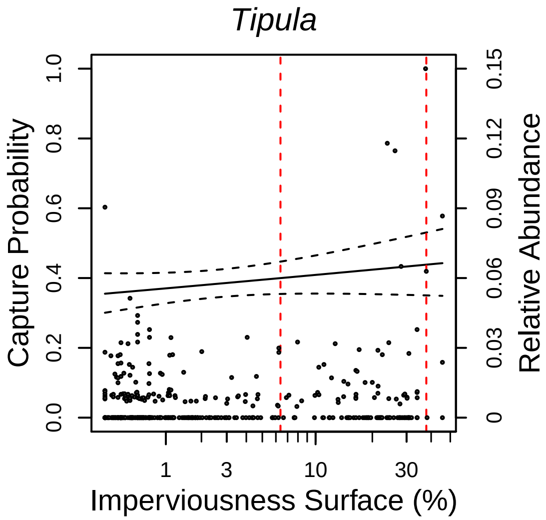
Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



Appendix F

Fish Capture Probability Modeled vs. Disturbance Gradient

Statistical approaches to determine indicator values (by Lei Zheng, Tetra Tech)

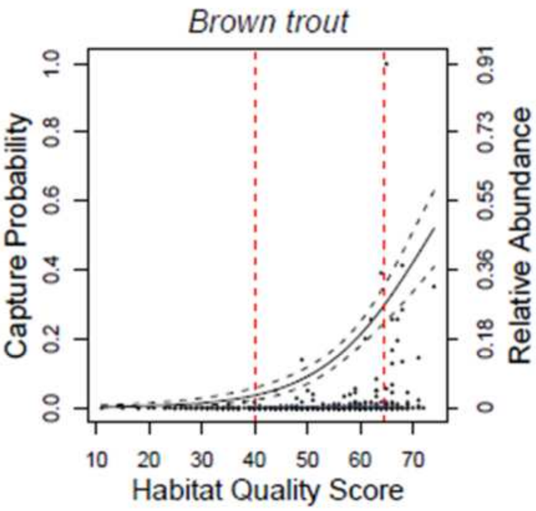
As described in Yuan's (2006) review of approaches for developing indicator values of biological community to various environmental stressors, four different statistical approaches could be applied: (1) central tendencies, (2) environmental limits, (3) optima, and (4) curve shapes. Tolerance values expressed in terms of central tendencies attempt to describe the average environmental conditions under which a species is likely to occur; indicator values expressed in terms of environmental limits attempt to capture the maximum or the minimum level of an environmental variable under which a species can persist; and indicator values expressed in terms of optima define the environmental conditions that are most preferred by a given species. These types of indicator values are expressed in terms of locations on a continuous numerical scale that represents the environmental gradient of interest. Both abundance-based and presence/absence-based models can be built using these statistical approaches.

The tolerance analyses for this project are based on MBSS Piedmont data (excluding limestone streams). The dataset consisted of 603 samples. Analyses were performed for the following 2 stressor variables: imperviousness and habitat score. Three groups of models were used in the analyses:

- Weighted averaging to estimate optima and tolerance values (abundance based)
- Cumulative distribution function median and extreme limits (presence/absence)
- Logistic regression (linear, nonlinear, generalized additive model) median and extreme limits (presence/absence)

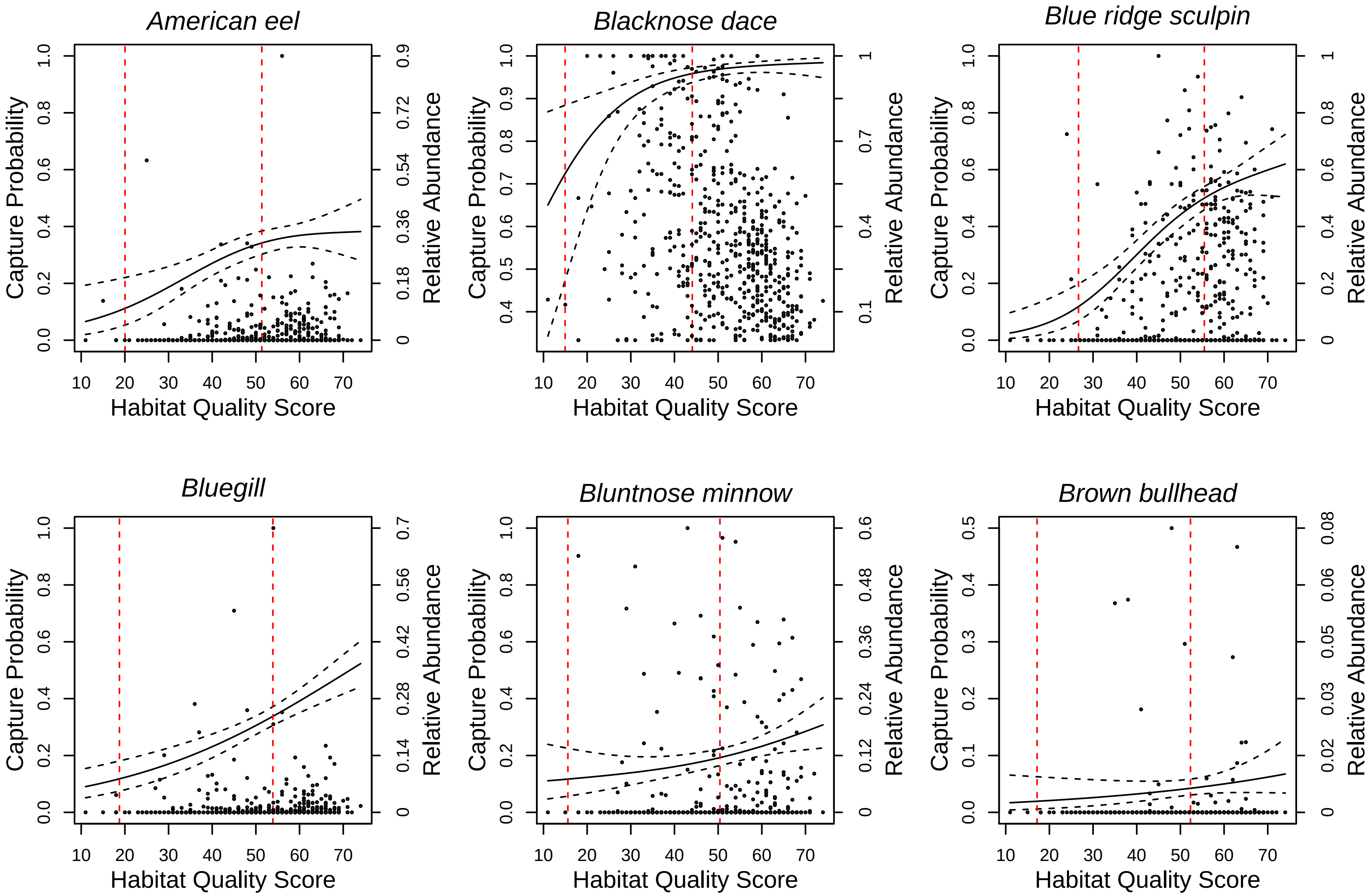
Taxon-response plots like the example shown below were generated for the taxa in the dataset. These were used to help inform BCG attribute assignments at the September 2013 workshop.

- Points: actual data of relative abundance
- Curve: capture probability (Generalized additive model fit and confidence interval)
- 5% capture probability and 50% probability (red dashed lines) represent tolerance and optimum
- Indicator values were ranked from 5 to 2

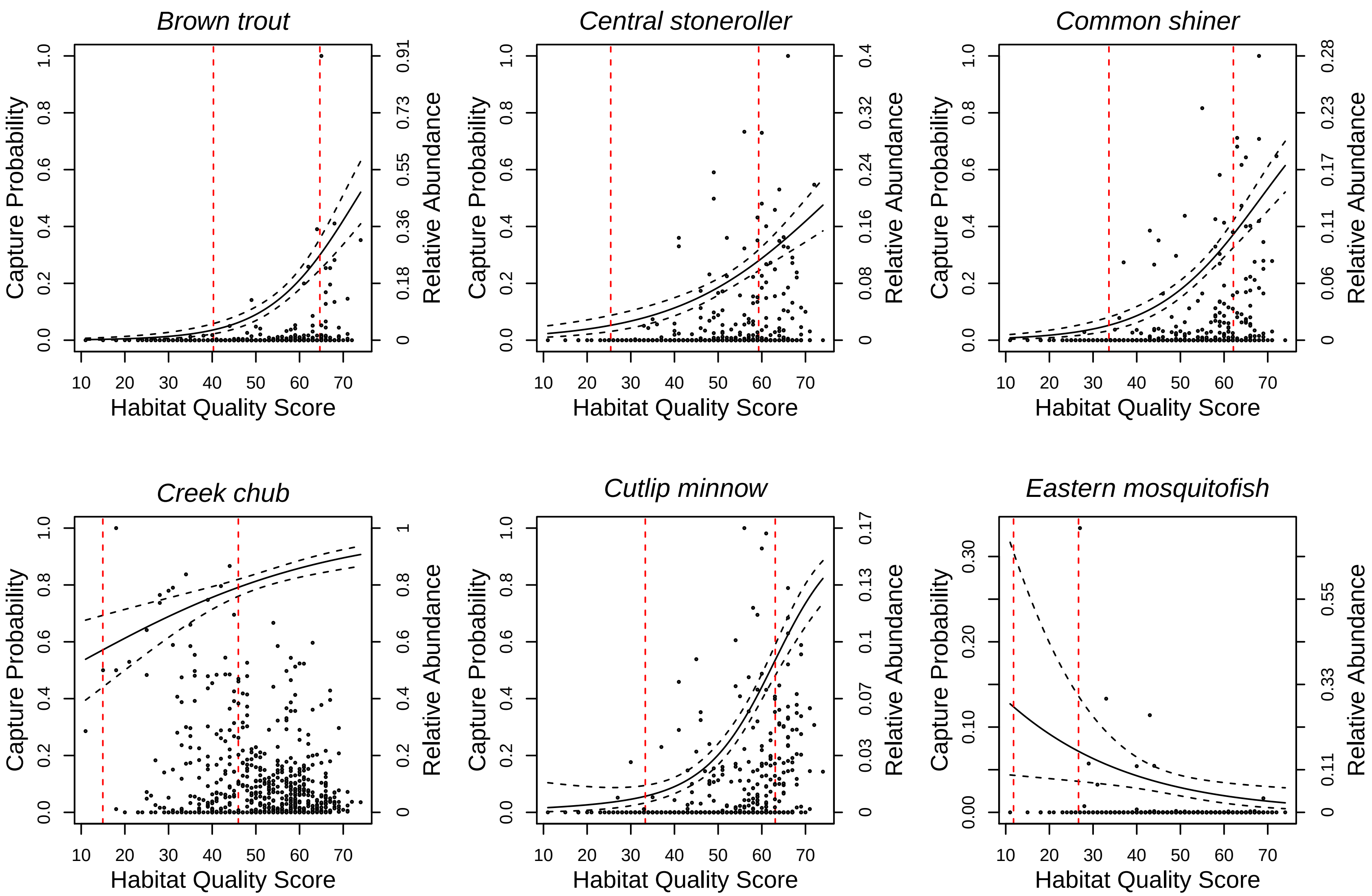


RESPONSES OF FISH TAXA TO HABITAT QUALITY

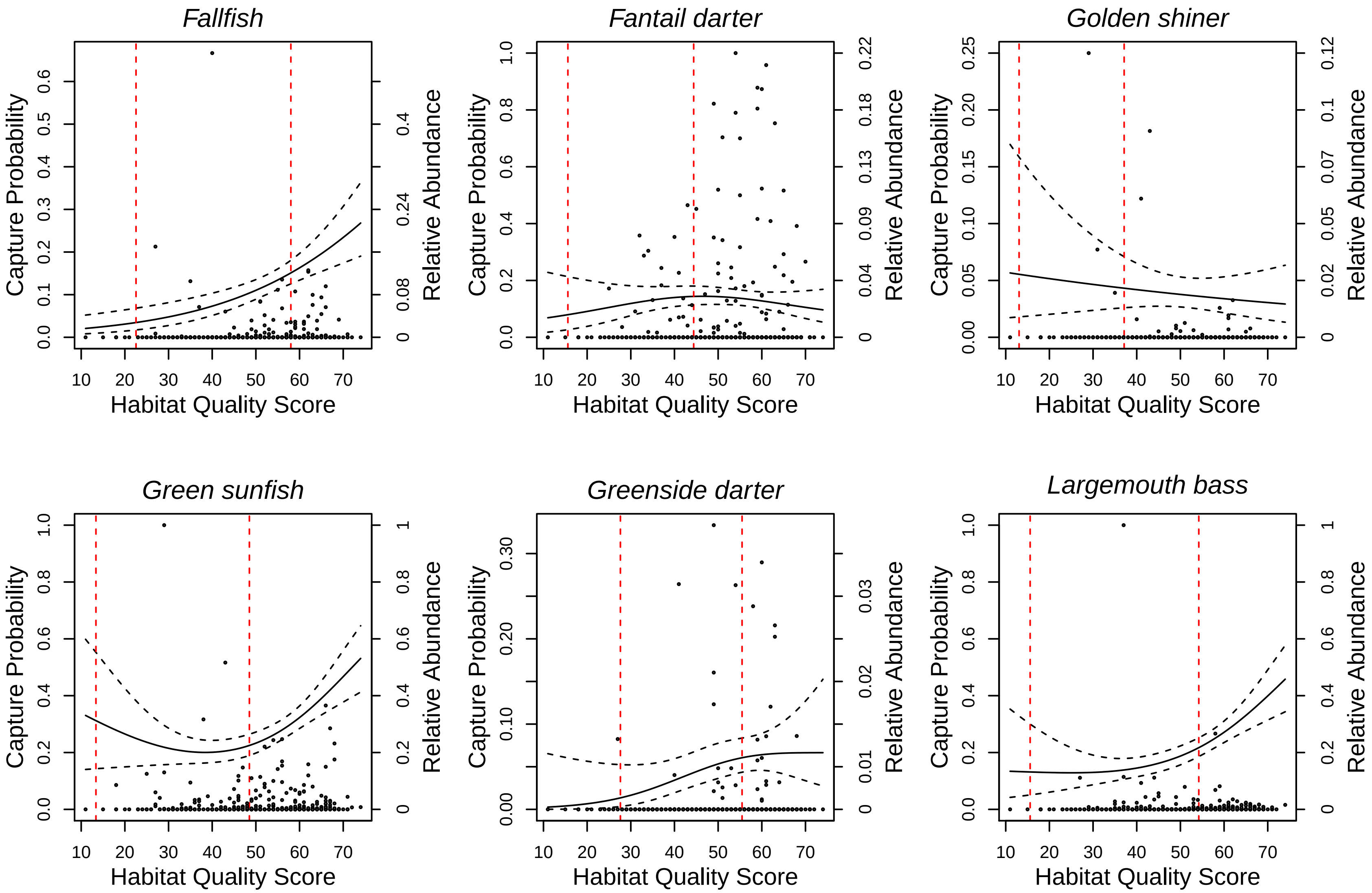
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



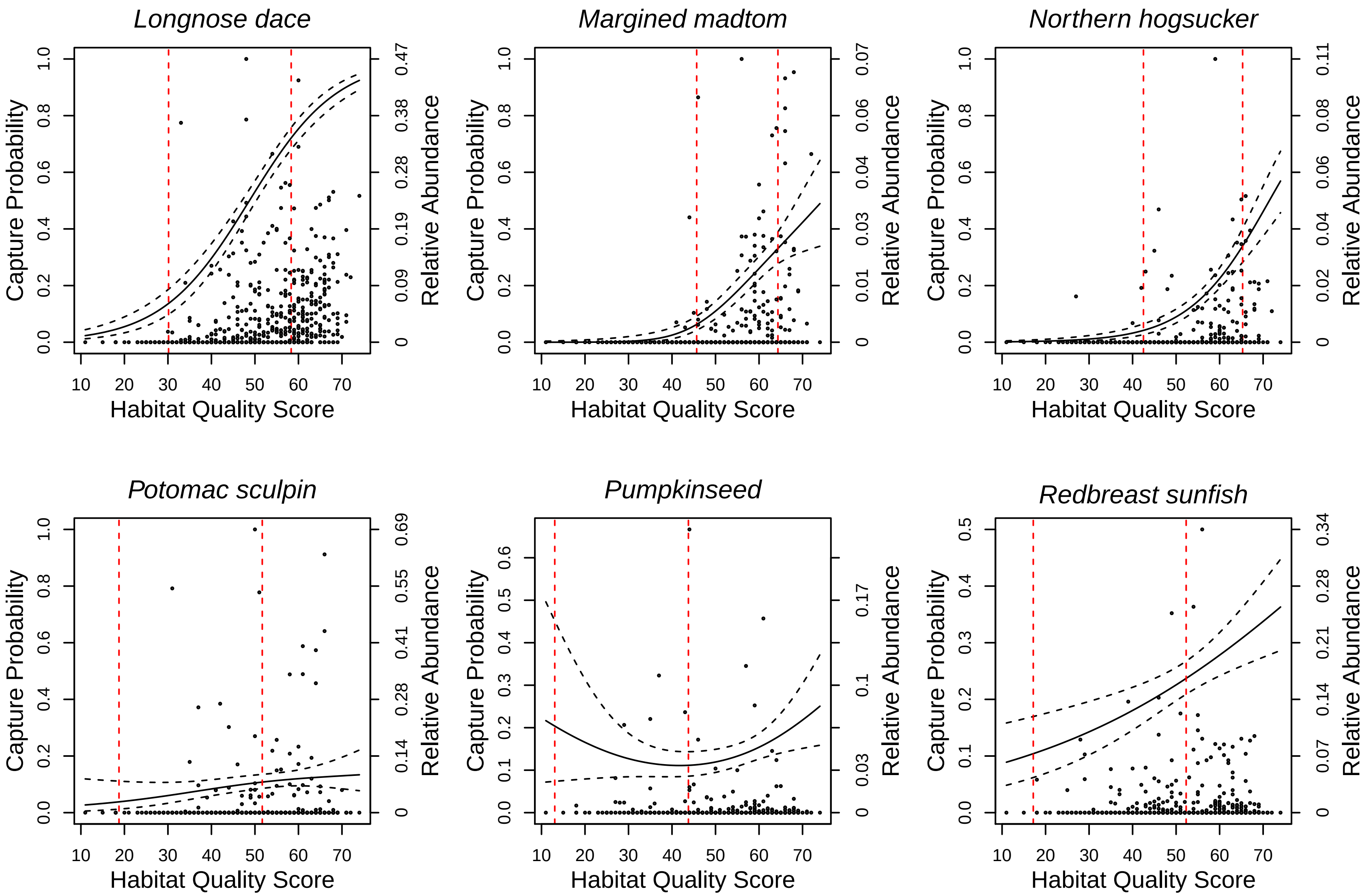
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



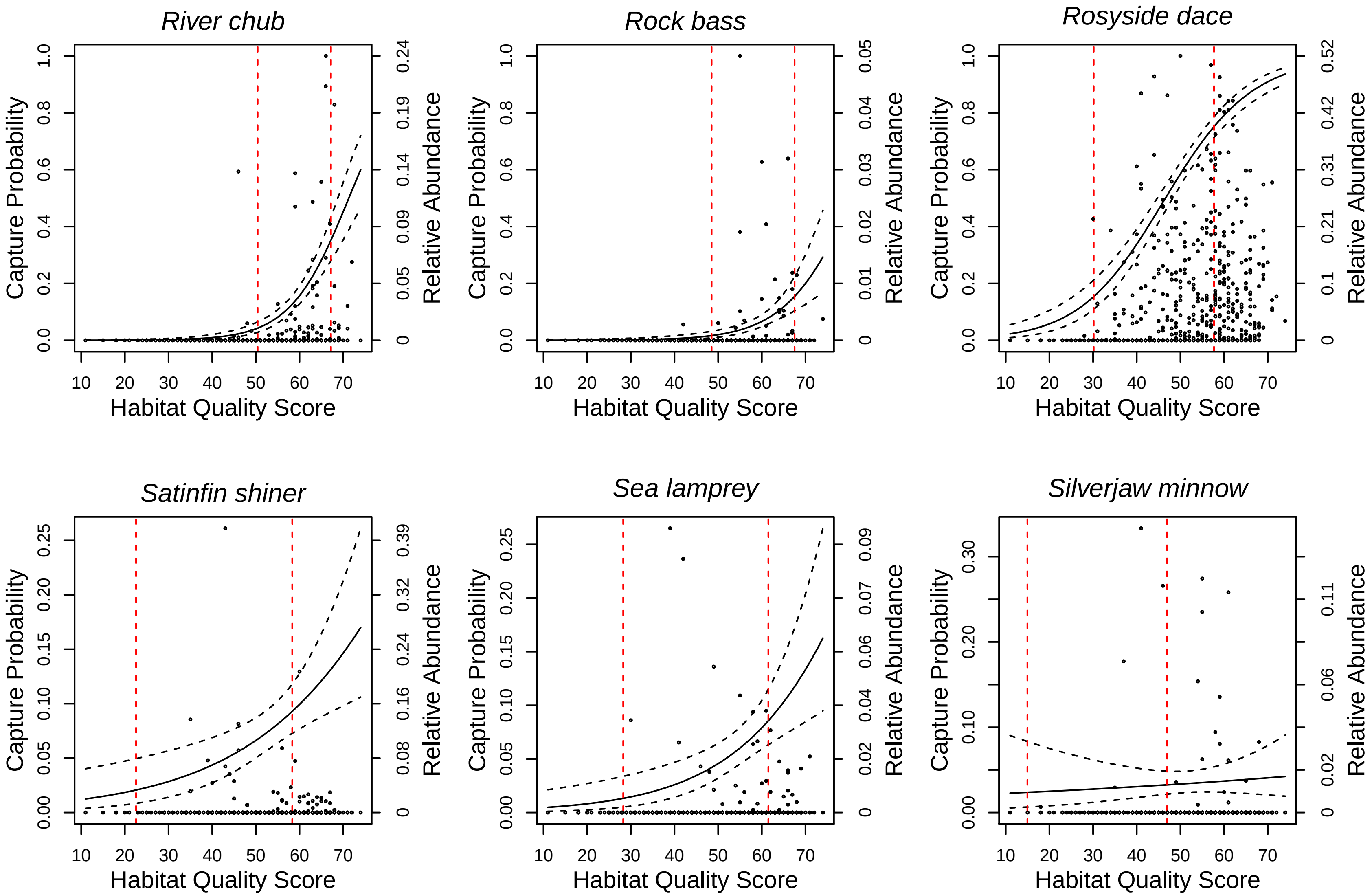
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



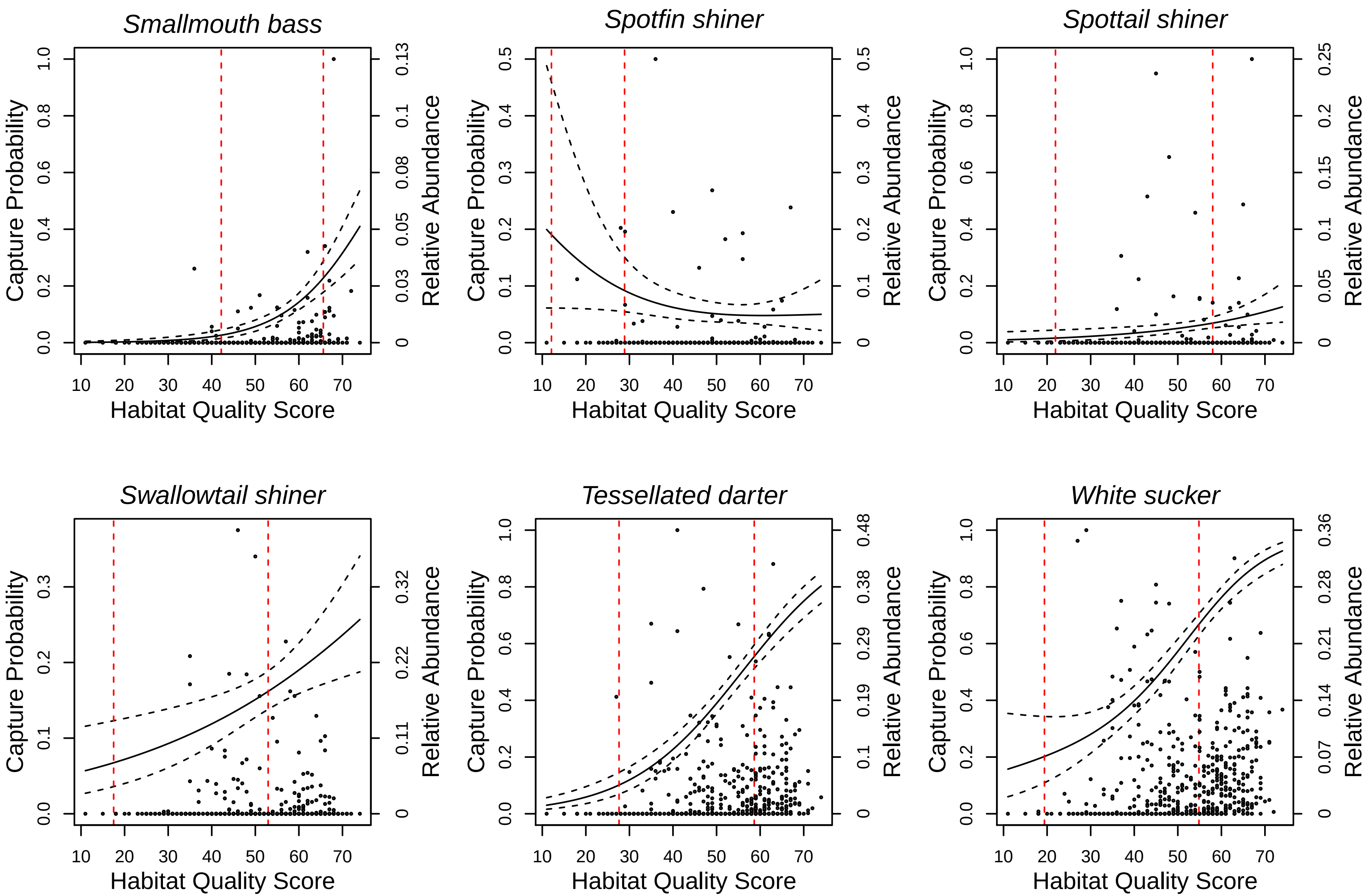
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



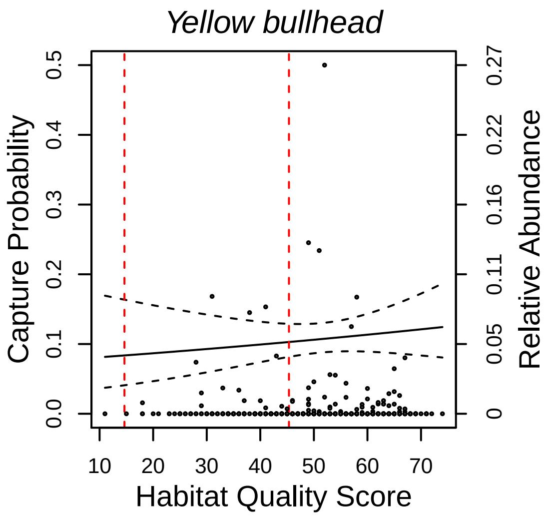
Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient



Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient

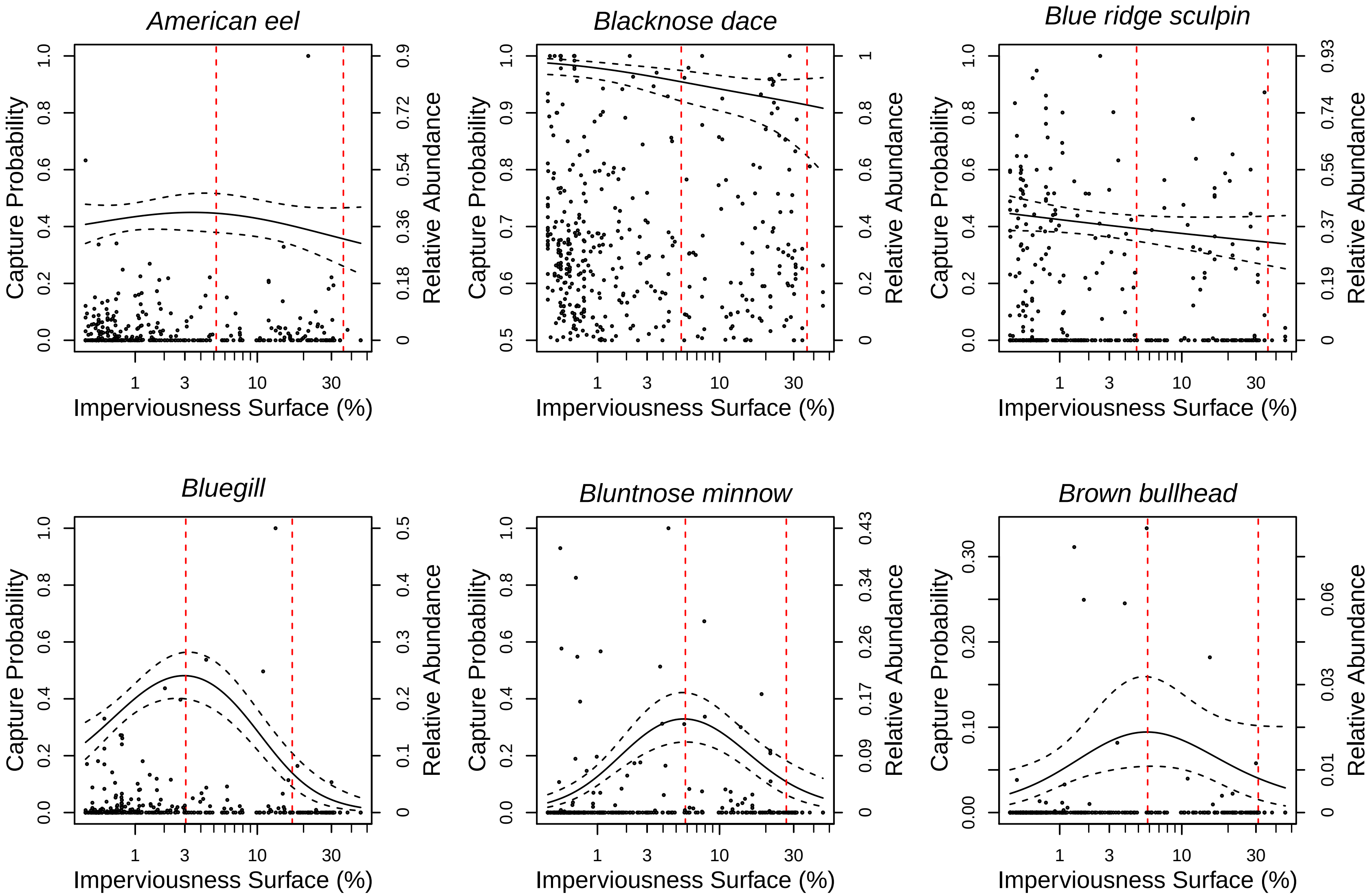


Capture Probability of Macroinvertebrate Taxon Along Habitat Gradient

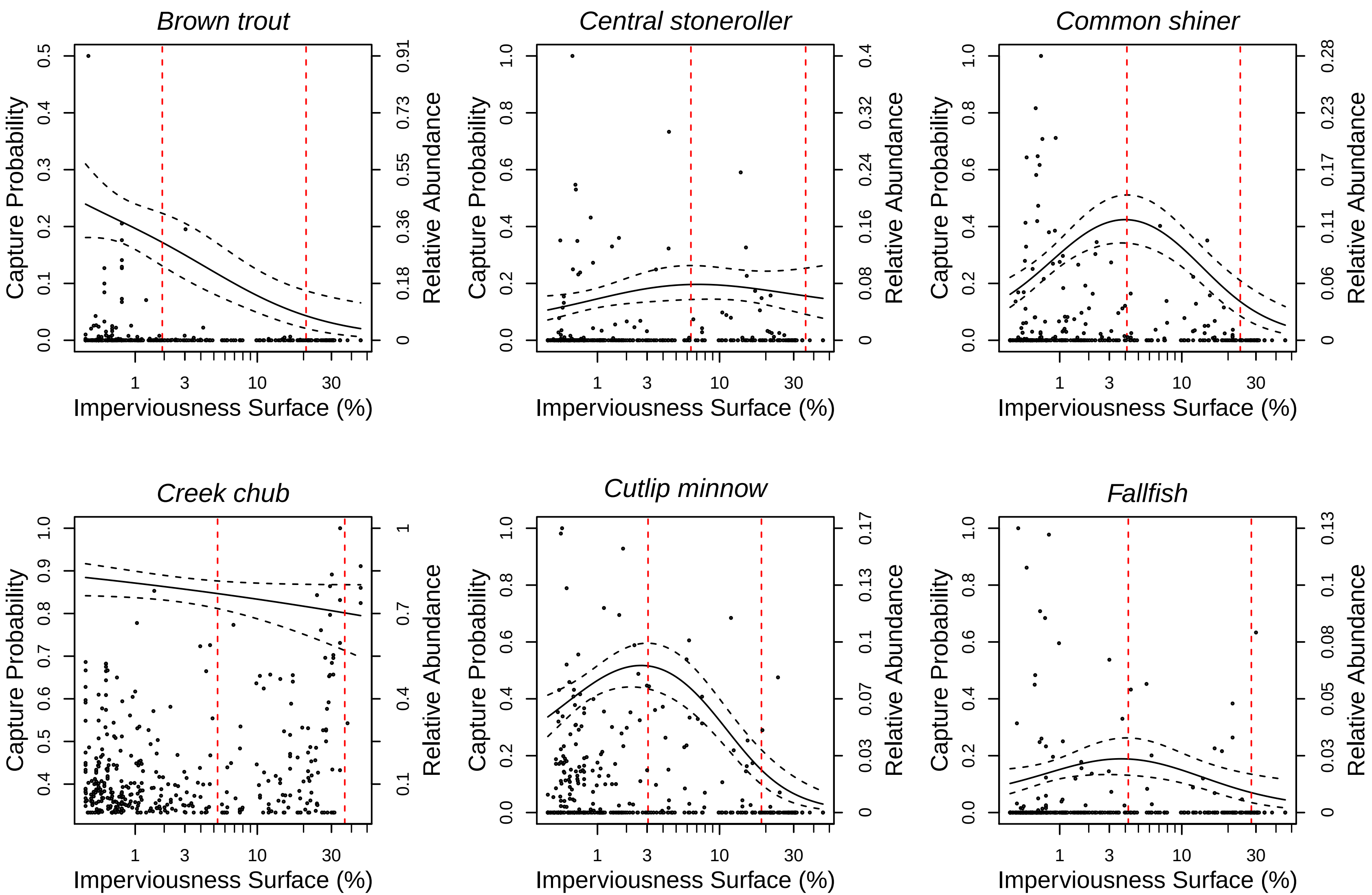


RESPONSES OF FISH TAXA TO % IMPERVIOUS SURFACE

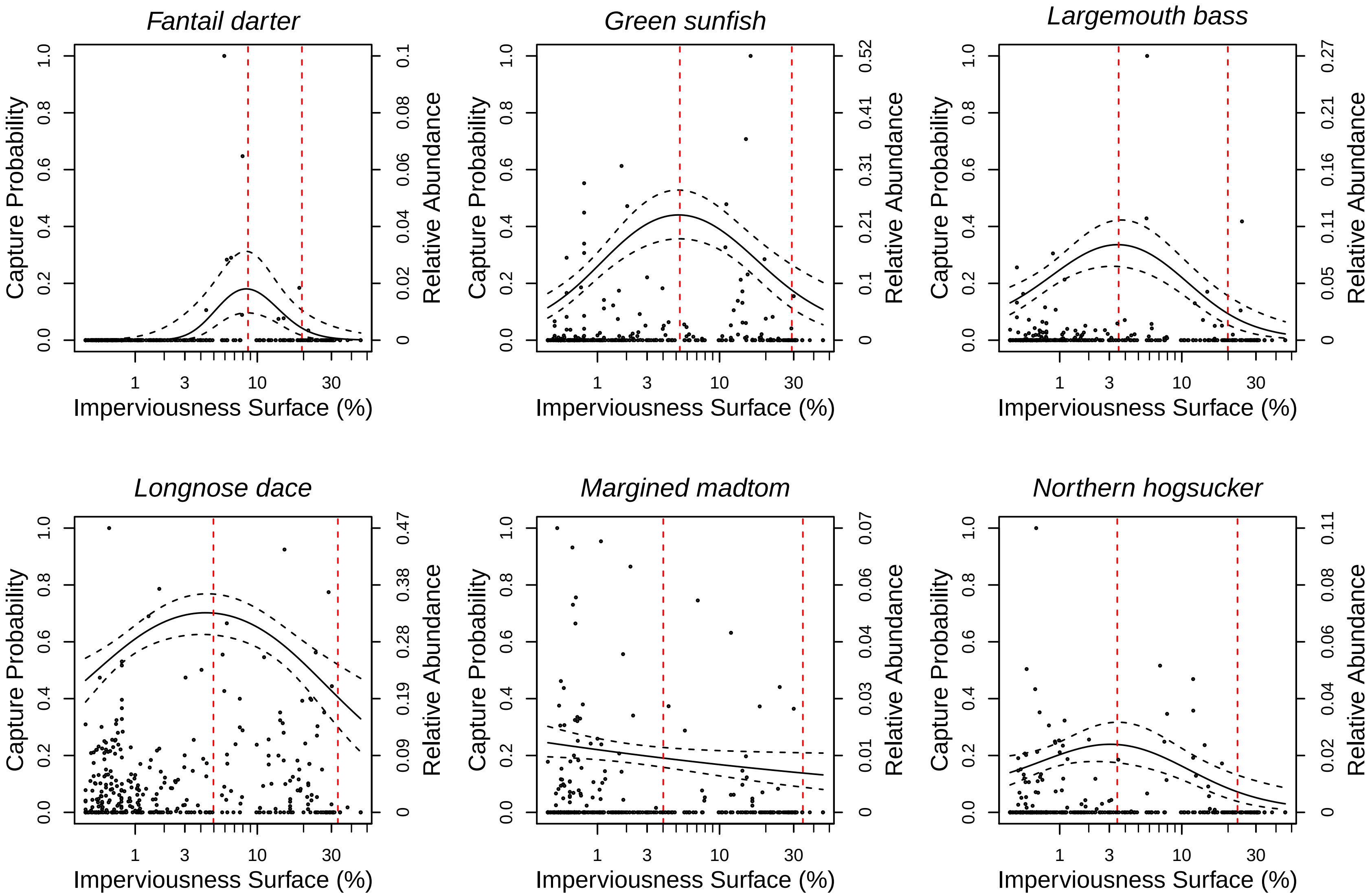
Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



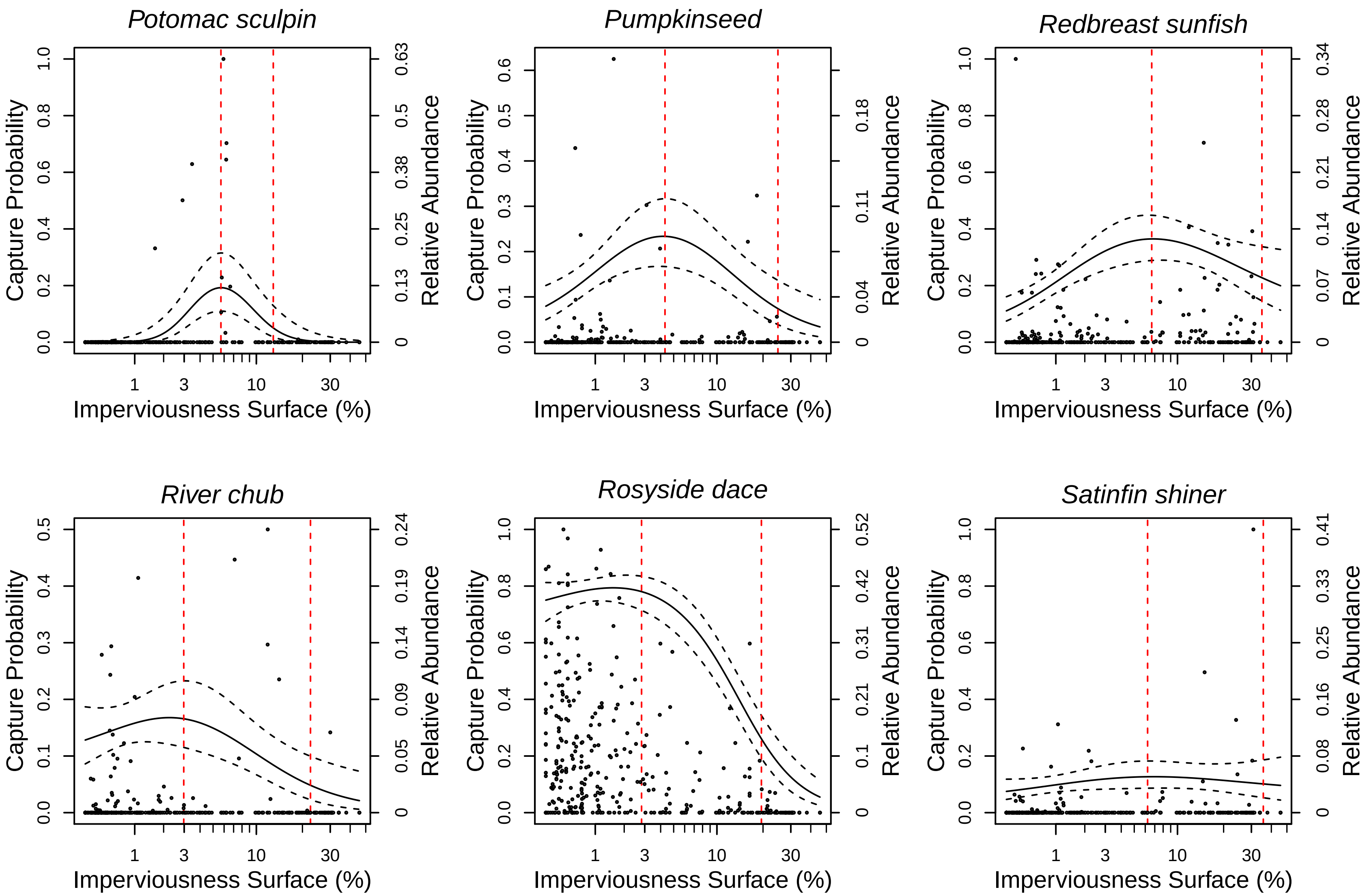
Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



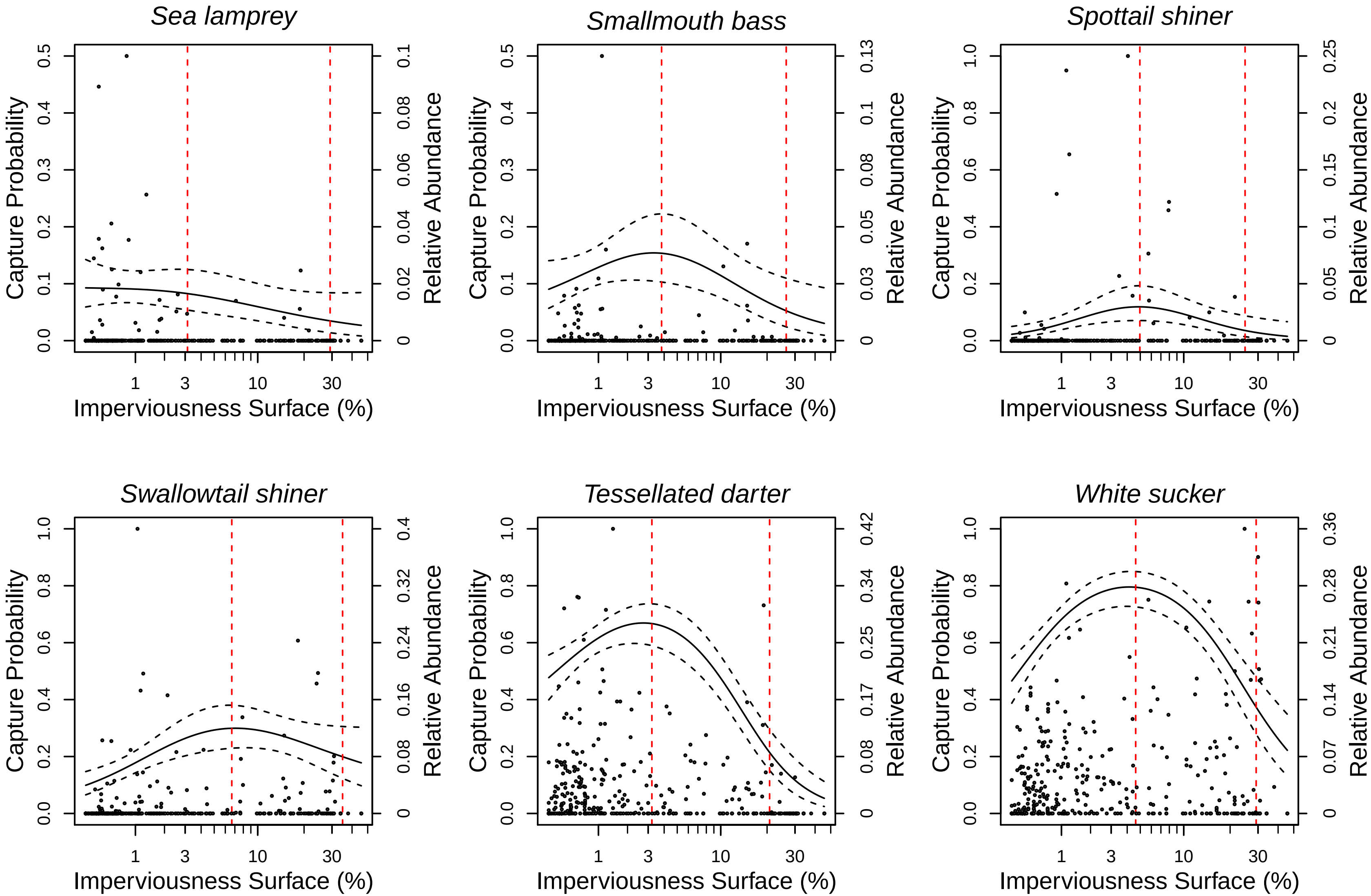
Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



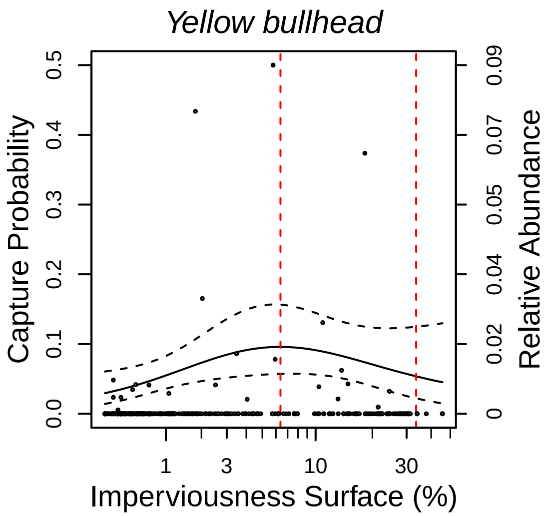
Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



Capture Probability of Macroinvertebrate Taxon Along Imperviousness Gradient



Appendix G

Sample Worksheets for Fish and Macroinvertebrates

Figure G1. Example of a fish/salamander worksheet that was used when making BCG level assignments.

ExerciseID	Samp046	Assigned Tier	Reasoning	
CollDate	6/26/2012	4+	4+, 4 to 3	
CollMethod	2PassE			
Attrib.	Number of Taxa	Num Ind	Pct Taxa	Pct Ind
1	0	0	0%	0%
2	0	0	0%	0%
3	3	40	30%	22%
4	2	20	20%	11%
5	4	106	40%	58%
6i	0	0	0%	0%
6m	0	0	0%	0%
6t	1	16	10%	9%
10	0	0	0%	0%
x	0	0	0%	0%
Total	*10*	*182*		

Go to StatusPage	articipantAssignments	
SiteID		StationID
StreamName		WaterbodyName
Parameter	**Value**	
Stream Class	0	StreamClass
WatershedArea_mi2	0.70	Area_mi2
Size Class	0.0	SizeClass
AvgJulyTemp	0.0	AvgJulyTemp
pctForest		LULC_For
Human Disturbance		HumanDisturbanceScore
Comments		Comments

att	Common Name	Scientific Name	Individuals
5	Blacknose dace	Rhinichthys atratulus	96
3	Blue Ridge sculpin	Cottus caeruleomentum	29
5	Creek chub	Semotilus atromaculatus	7
4	Fantail darter	Etheostoma flabellare	12
6t	Green sunfish	Lepomis cyanellus	16
4	Longnose dace	Rhinichthys cataractae	8
3	Potomac sculpin	Cottus girardi	2
3	Rosyside dace	Clinostomus funduloides	9
5	White sucker	Catostomus commersonii	1
5	Yellow bullhead	Ameiurus natalis	2

No Salamanders Observed

NAME	RATING	REASONING
Scott	3-	hi div for small stream, att 5 expected in this
Jai		
Ken	3-	no top pred or sal
Charlie	3	good div for small stream
Jim	4+	should have sal
Lou	4+	should be eel, sals,
Keith	4	small, but no sal, hi % att 5
Frank	4	same as Keith
Eric	4	
Consensus	4 to 3	developing watershed, sediment

Figure G2. Example of a macroinvertebrate worksheet that was used when making BCG level assignments.

ExerciseID	Samp052	Assigned Tier	Reasoning		Go to StatusPage	ParticipantAssignments	
CollDate	3/24/2009	3+	2- to 3		SiteID		StationID
CollMeth	20jab		Previous Designation		StreamName		WaterbodyName
BCG Attribute	**Number of Taxa**	**Num Ind**	**Pct Taxa**	**Pct Ind**	**Parameter**	**Value**	
1	0	0	0%	0%	Stream Class	0	StreamClass
2	3	7	11%	6%	WatershedArea_mi2	0.7	Area_mi2
3	14	73	50%	66%	Size Class	0.0	SizeClass
4	8	16	29%	15%	AvgJulyTemp	0	AvgJulyTemp
5	2	13	7%	12%	pctForest		LULC_For
6	0	0	0%	0%	Human Disturbance		HumanDisturbanceScore
x	1	1	4%	1%	Gradient (m/km)	0.0	Gradient
Total	*28*	*110*					

BCG Attribute	FinalID	Individuals	Order	Family (Tribe)
3	Acroneuria	3	Plecoptera	Perlidae
3	Ameletus	9	Ephemeroptera	Ameletidae
3	Anchytarsus	7	Coleoptera	Ptilodactylidae
4	Chelifera	1	Diptera	Empididae
4	Cheumatopsyche	4	Trichoptera	Hydropsychidae
4	Clinocera	1	Diptera	Empididae
3	Diplectrona	5	Trichoptera	Hydropsychidae
3	Dolophilodes	1	Trichoptera	Philopotamidae
x	Elmidae	1	Coleoptera	Elmidae
2	Epeorus	5	Ephemeroptera	Heptageniidae
3	Ephemerellidae	2	Ephemeroptera	Ephemerellidae
5	Eukiefferiella	7	Diptera	Chironomidae
3	Glossosoma	1	Trichoptera	Glossosomatidae
4	Hydropsyche	3	Trichoptera	Hydropsychidae
3	Leuctridae	1	Plecoptera	Leuctridae
3	Neophylax	2	Trichoptera	Uenoidae
4	Optioservus	1	Coleoptera	Elmidae
5	ORTHOCLADIINAE	6	Diptera	Chironomidae
3	Oulimnius	1	Coleoptera	Elmidae
3	Perlidae	1	Plecoptera	Perlidae
2	Perlodidae	1	Plecoptera	Perlodidae
2	PRODIAMESINAE	1	Diptera	Chironomidae
3	Prosimulium	36	Diptera	Simuliidae
3	Prostoia	3	Plecoptera	Nemouridae
4	Stenonema	1	Ephemeroptera	Heptageniidae
3	Taeniopteryx	1	Plecoptera	Taeniopterygidae
4	TANYTARSINI	2	Diptera	Chironomidae
4	Tipula	3	Diptera	Tipulidae

29-Apr	Name	Rating	reasoning
	Ellen Dickey	2-	
	Adam Griggs	3+	Sens rares being replaced with Sesns Ubiq.; good taxa list but not a 3
	Laurie Alexander	2-	
	Ellen Friedman	2-	like diversity of the sensitive taxa
	Warren Smigo		
	Chris Luckett	2-	presence of tolerant not imp, but drop off of some expected 2s
	Alan E	2-	good list some missing; not worried about Prosimulium; other 2's missing for a solid 2
	Bill S	3+	
	Dave S	3+	ditto Chris and Adam--need more 2s
	Jeanne C	3+	low att. 2 but cold.;
	Dave J	3+	
	Mattt H	3+	more 4s than expected for tier 2
	Neal	3	more 2 taxa required
	Mattt B	3+	low abun of a few 3 taxa; but high abund of other 3

Appendix H

BCG Level Assignments – Macroinvertebrates

Participants made BCG level assignments on 46 macroinvertebrate samples for the calibration exercise and 14 samples for the confirmation exercise. Samples were assessed using the scoring scale shown in Table H1.

Table H1. Scoring scale that was used for making BCG level assignments.

best	1
	1-
	2+
	2
	2-
	3+
	3
	3-
	4+
	4
	4-
	5+
	5
	5-
	6+
	6
worst	6-

Table H2 contains BCG level assignments from panelists and the BCG model for the calibration samples and Table H3 has the same information for the confirmation samples.

Table H2. BCG level assignments and sample information for macroinvertebrate samples that were assessed during the calibration exercise. BCG level assignments are as follows: Final=consensus BCG level (=the assignment made by the majority of participants); Best= the best BCG level assignment assigned by a participant (based on the scoring scale in Table H1); Worst=the worst BCG level assignment given by a participant. Samples are highlighted in yellow if the consensus call from the panelists is different from the primary call from the model.

SITEYR	Exercise ID	Collection Date	Waterbody Name	Area (mi2)	Panelist consensus			Primary model
					Final	Best	Worst	
BCBC211_1999	Samp047	4/29/1999	Bennett Creek	0.78	3+	2-	4+	2
BCBC301_2003	Samp048	4/24/2003	Bennett Creek	2.62	4+	3-	4+	4
DEER-118-R-2004	Samp055	3/25/2004	Deer Cr UT7	0.60	2-	2	3+	2
FURN-101-S-2005	Samp056	4/5/2005	Principio Cr UT1	1.10	2-	2	3+	2
FURN-101-S-2009	Samp054	3/25/2009	Principio Cr UT1	1.10	2-	2-	3+	2
HBHB302_2010	Samp021	5/4/2010	Mount Nebo Tributaries	5.82	4	4	4-	4
HWGT204_2010	Samp022	4/28/2010	Gregg Road Tributary	3.21	3	3+	3-	3
HWHW308B_2010	Samp023	4/28/2010	Upper Hawlings River	9.64	4+	3-	4	4
HWJC301_2010	Samp024	4/23/2010	James Creek	3.27	5	5+	5-	5
LBKT304_2008	Samp015	5/7/2008	Kingsley Trib.	1.50	4	4	4	4
LBSB201A_2012	Samp014	3/28/2012	Sopers Br.	1.20	3+	3+	3	3
LFLF301C_2007	Samp012	4/19/2007	Little Falls	4.70	5/6	5	6	5/6 tie
LIBE-102-S-2009	Samp053	3/23/2009	Timber Run	0.90	2-	2	3+	2
LOCH-120-S-2009	Samp052	3/24/2009	Baisman Run	0.70	3+	2-	3	2
LOGU-280-M-2003	Samp057	4/8/2003	Minebank Run	3.40	6	6	6	6
LPAT201_2010	Samp018	4/29/2010	Aitchinson Trib.	0.90	3+	2-	3	3
LPAT201b_2010	Samp026	4/29/2010	Aitchinson Trib.	0.92	3	3	3-	3
LPRG204_2010	Samp028	4/29/2010	Ednor Tributaries	1.31	4+	3-	4	4
LRLR201_2012	Samp029	4/18/2012	Hoyt Creek	1.33	5	5+	6	5
LRTB203C_2012	Samp011	4/16/2012	Turkey Branch	3.80	6+	5-	6	5
LRTB203Cb_2012	Samp030	4/16/2012	Turkey Branch	3.78	5	5	6	5
LSCT103_2006	Samp013	3/28/2006	Churchil Trib	0.70	5-	5	6	5
LSLS104_1998	Samp004	4/7/1998	Clarksburg Trib.	0.40	3	3+	3-	3
LSLS104b_2012	Samp005	3/26/2012	Clarksburg Trib.	0.40	4-	4	5+	4

Table H2 continued…

SITEYR	Exercise ID	Collection Date	Waterbody Name	Area (mi2)	Panelist consensus			Primary model
					Final	Best	Worst	
LSLS206_2012	Samp050	3/21/2012	Clarksburg Tributary	0.75	4-	4+	4-	4
LSTM110_2012	Samp001	3/29/2012	King Spr	0.30	2/3	2	3	3
LSTM110b_2012	Samp031	3/29/2012	King Spr	0.33	3-	3+	4+	3
LSTM110c_2013	Samp032	3/26/2013	King Spr	0.33	3+	3+	3	3
LSTM202_2012	Samp033	3/29/2012	Little Seneca Creek - Ten Mile Creek	0.95	4	4+	4	4
LSTM303B_2012	Samp002	3/28/2012	Ten Mile	3.50	4	3-	4	4
LSTM304_2012	Samp003	3/28/2012	Ten Mile_Gage	4.40	4	3-	4	4
MBMB201_2007	Samp049	4/23/2007	Pennyfield Mainstem	0.62	3	3	3-	3
NWBP205_2011	Samp020	3/14/2011	Bel Pre	3.60	5	4-	5	5
NWBP205b_2011	Samp036	3/14/2011	Bel Pre	3.61	5	5	6+	5
NWNW206A_2011	Samp037	4/6/2011	Northwest Branch - Right Fork	1.30	3-	3	4	3
PBGH208A_2012	Samp038	3/6/2012	Good Hope Tributary	1.31	4	4	5+	4
PBHB210_2011	Samp040	3/14/2011	Hollywood Branch	1.54	5-	5	6	5
PBRF206_1998	Samp006	4/1/1998	Right Fork	1.30	3	2	3	3
PBRF206b_2012	Samp007	4/17/2012	Right Fork	1.30	4-	4	5	4
SCBT101_2012	Samp041	3/19/2012	Breewood Tributary	0.08	6	6+	6	6
SCSC301_2011	Samp051	4/20/2011	Upper Sligo Creek Mainstem	3.11	6	6	6	6
UPPR201A_2010	Samp042	5/4/2010	Upper Brighton Dam - Damascus Tributaries	1.28	3+	3+	3	3
URMC304_2012	Samp043	4/16/2012	Upper Rock Creek - Mill Creek	3.24	5	4-	6	5
URSV201_2012	Samp045	4/11/2012	Upper Rock Creek	0.33	4+	3-	4	4
WBPB201_1997	Samp008	4/3/1997	Piney Br.	0.50	4+	3	4-	4
WBPB201b_2012	Samp009	4/5/2012	Piney Br.	0.50	5	5+	5-	5

Table H3. BCG level assignments and sample information for macroinvertebrate samples that were assessed during the confirmation exercise. BCG level assignments are as follows: Final=consensus BCG level (=the assignment made by the majority of participants); Best= the best BCG level assignment assigned by a participant (based on the scoring scale in Table H1); Worst=the worst BCG level assignment given by a participant. Samples are highlighted in yellow if the consensus call from the panelists is different from the primary call from the model.

SITEYR	Exercise ID	Collection Date	Waterbody Name	Area (mi2)	Panelist consensus			Primary model
					Final	Best	Worst	
BELK-110-R-2003	Samp060	4/9/2003	GRAMIES RUN	0.40	3+	2-	3	3
DEER-207-R-2001	Samp058	3/8/2001	BIG BRANCH	4.10	2-	2	3	2
LIBE-266-A-2007	Samp059	3/21/2007	LITTLE MORGAN RUN	5.17	3+	3+	3	3
LPLP202_2011	Samp027	4/4/2011	Tanglewood Tributary	0.93	5-	5	6+	5
LSTM111_2012	Samp061	3/29/2012	Little Seneca Creek - Ten Mile Creek	0.16	3-	3+	4+	4
LSTM112_2013	Samp064	3/21/2013	Little Seneca Creek - Ten Mile Creek	0.35	2-	2	3+	2/3 tie
LSTM201_2013	Samp066	3/26/2013	Little Seneca Creek - Ten Mile Creek	0.95	2-	2	3+	2
LSTM202_2013	Samp067	3/26/2013	Little Seneca Creek - Ten Mile Creek	0.95	4+	3-	4	4
LSTM204_2012	Samp070	3/30/2012	Little Seneca Creek - Ten Mile Creek	0.77	3+	2-	3	3
LSTM204_2013	Samp071	3/21/2013	Little Seneca Creek - Ten Mile Creek	0.85	3	3+	3-	3
LSTM302_2012	Samp034	3/30/2012	Little Seneca Creek - Ten Mile Creek	3.15	4+	3	4	4
LSTM303B_2012_sub	Samp035	3/28/2012	Ten Mile	3.50	4	4+	4-	4
LSTM304_2013	Samp075	3/27/2013	Ten Mile_Gage	4.40	3+	2-	3+	3
URNB205_2012	Samp044	4/12/2012	Williamsburg Run	1.59	5	4-	5-	5

Appendix I

Box Plots of All Metrics – Macroinvertebrates

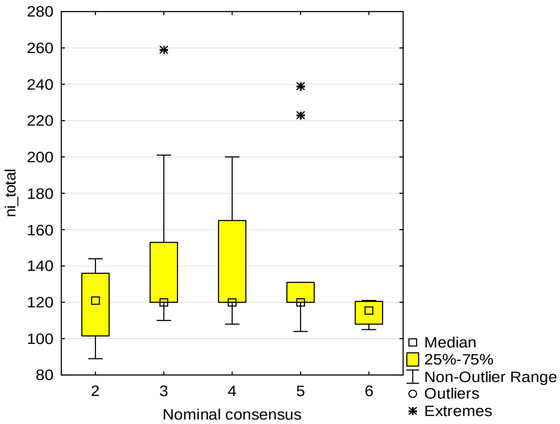
Box plots were generated to examine the distributions of metric values across BCG levels. Table I1 contains descriptions of the metric codes that are on the y-axes of the plots.

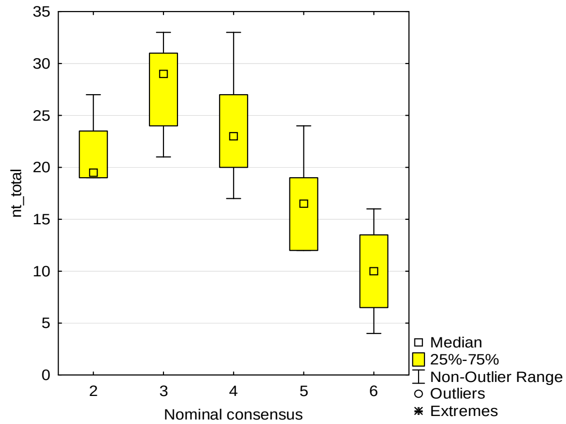
TableI1. Descriptions of the metric codes that are on the y-axes of the box plots.

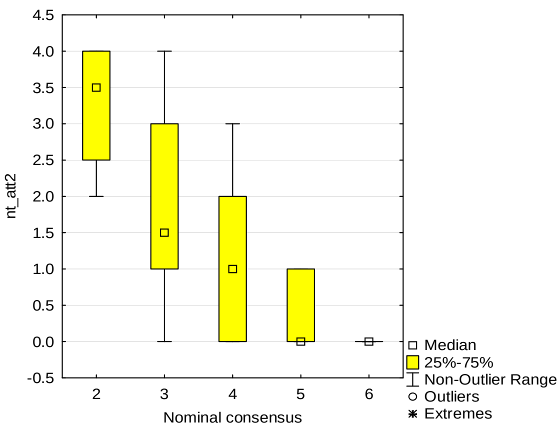
Metric code	Description
ni_total	number of total individuals
nt_total	number of total taxa
nt_att2	number of attribute 2 taxa
nt_att23	number of attribute 2 + 3 taxa
nt_att3	number of attribute 3 taxa
nt_att4	number of attribute 4 taxa
nt_att5	number of attribute 5 taxa
nt_att56	number of attribute 5 + 6 taxa
nt_att6	number of attribute 6 taxa
pt_att2	percent attribute 2 taxa
pt_att23	percent attribute 2 + 3 taxa
pt_att3	percent attribute 3 taxa
pt_att4	percent attribute 4 taxa
pt_att5	percent attribute 5 taxa
pt_att56	percent attribute 5 + 6 taxa
pt_att6	percent attribute 6 taxa
pi_att2	percent attribute 2 individuals
pi_att23	percent attribute 2 + 3 individuals
pi_att3	percent attribute 3 individuals
pi_att4	percent attribute 4 individuals
pi_att5	percent attribute 5 individuals
pi_att56	percent attribute 5 + 6 individuals
pi_att6	percent attribute 6 individuals
pi_dom01_att3	percent individuals - dominінant attribute 3 taxon
pi_dom01_att4	percent individuals - domininant attribute 4 taxon
pi_dom01_att5	percent individuals - domininant attribute 5 taxon
nt_EPT	number to EPT taxa
nt_EPTsensitive	number of sensitive EPT taxa (TV 0 Or 1 Or 2 Or 3)
pi_EPT	percent individuals - EPT taxa
pi_EPTsensitive	percent individuals - sensitive EP taxa
pt_EPT	percent EPT taxa
pt_EPTsensitive	percent sensitive EPT taxa
pi_Chiro	percent Chironomidae individuals
pi_Oligo	percent Oligochaeta individuals
nt_cold	number of cold water taxa
pt_cold	percent cold water taxa
pi_cold	percent individuals - cold water taxa

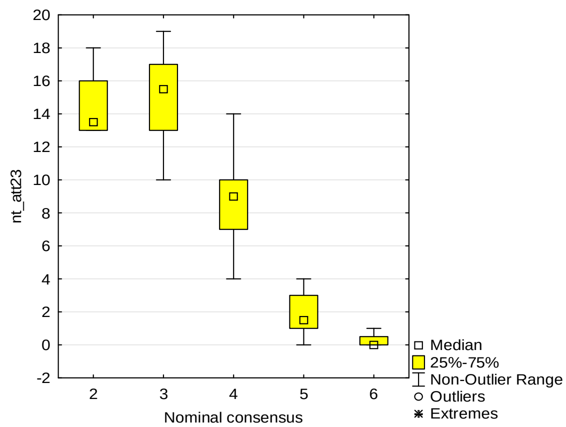
TableI1. continued…

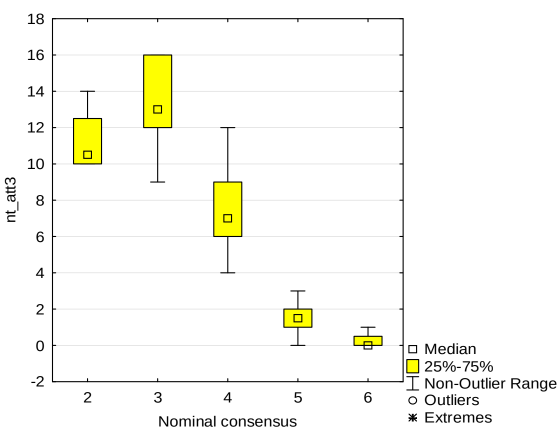
Metric code	**Description**
nt_NonInsect5	number of non-insect attribute 5 taxa
pt_NonInsect5	percent non-insect attribute 5 taxa
pi_NonInsect5	percent individuals - non-insect attribute 5 taxa

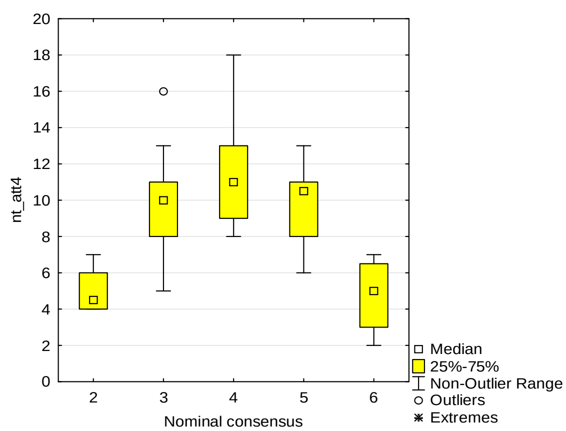

ni_total
280
260
240
220
200
180
160
140
120
100
80
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

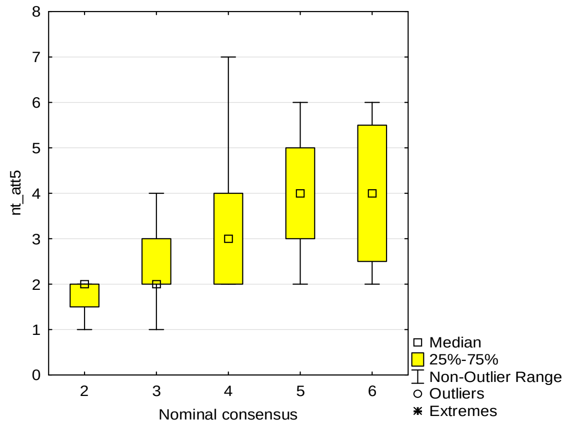

nt_total
35
30
25
20
15
10
5
0
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

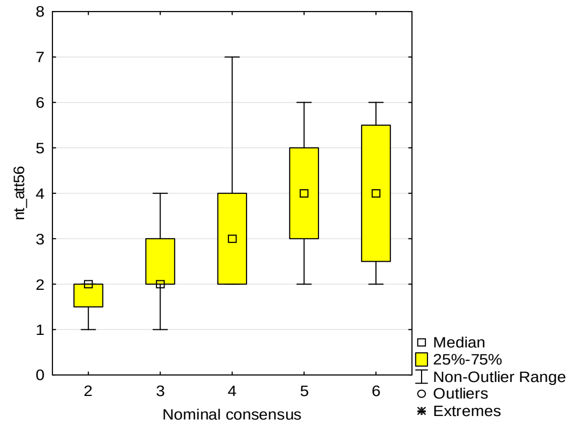

nt_att2
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

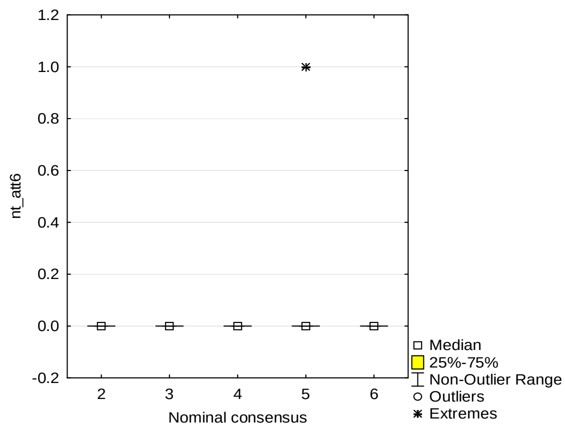

nt_att23
20
18
16
14
12
10
8
6
4
2
0
-2
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

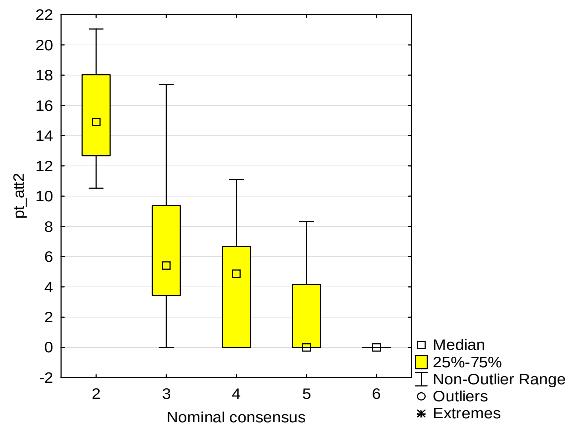

nt_att3
18
16
14
12
10
8
6
4
2
0
-2
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

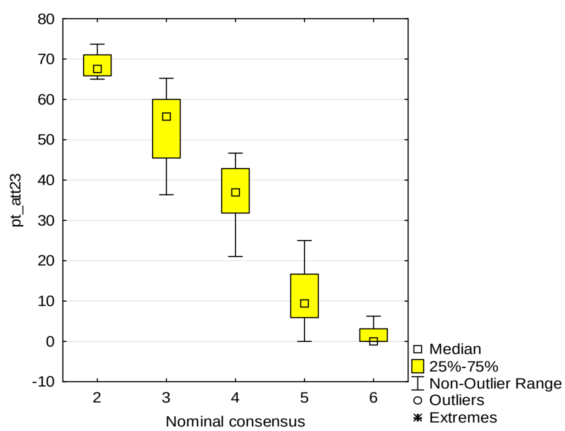

nt_att4
20
18
16
14
12
10
8
6
4
2
0
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

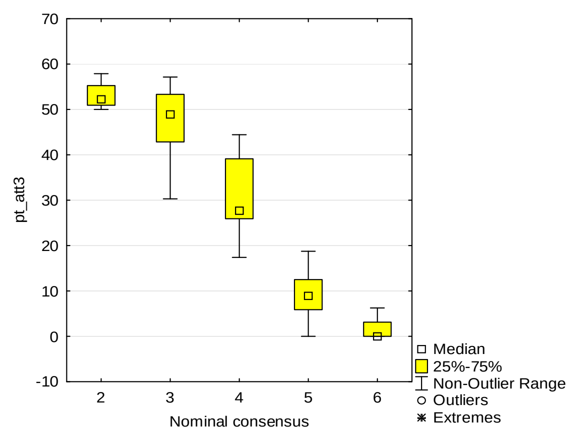

nt_att5
0
1
2
3
4
5
6
7
8
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

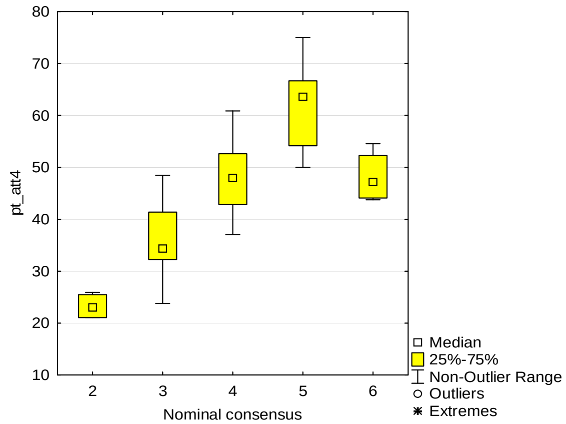

nt_att56
0
1
2
3
4
5
6
7
8
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

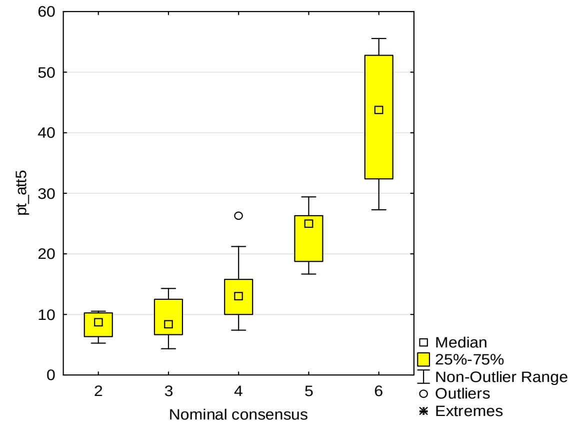

nt_att6
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

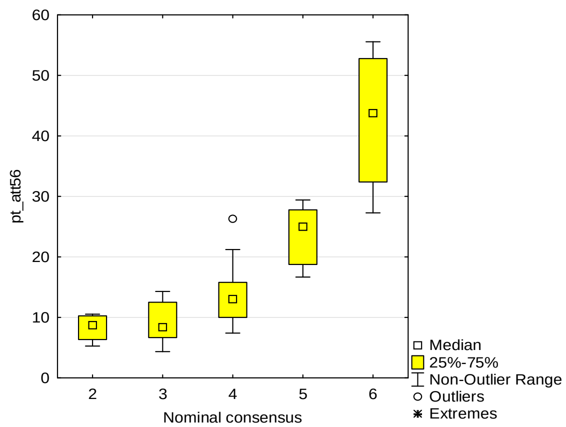

pt_att2
-2
0
2
4
6
8
10
12
14
16
18
20
22
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

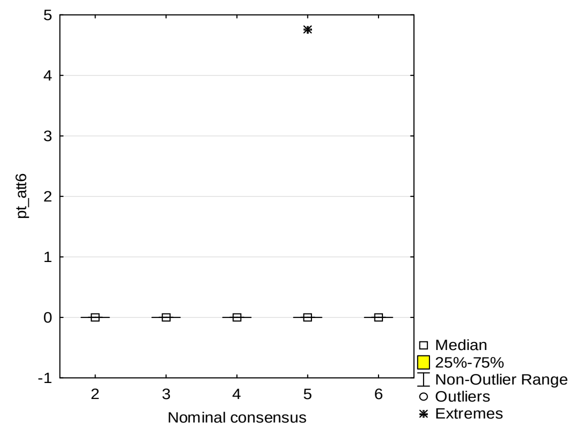

pt_att23
-10
0
10
20
30
40
50
60
70
80
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

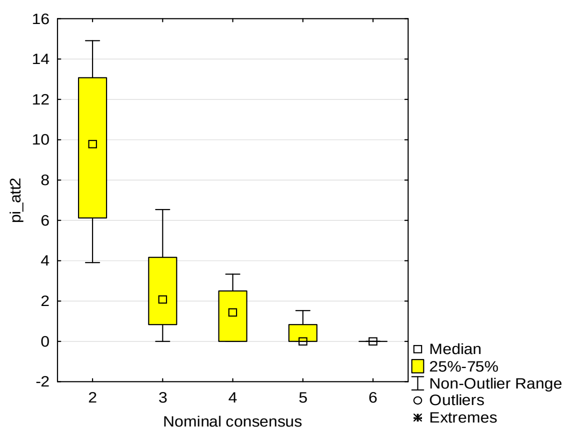

pt_att3
-10
0
10
20
30
40
50
60
70
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

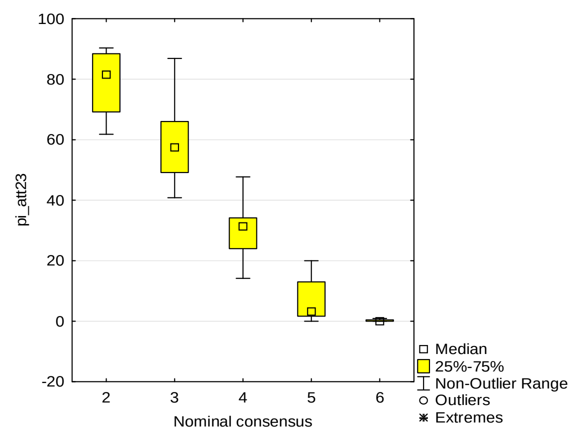

pt_att4
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

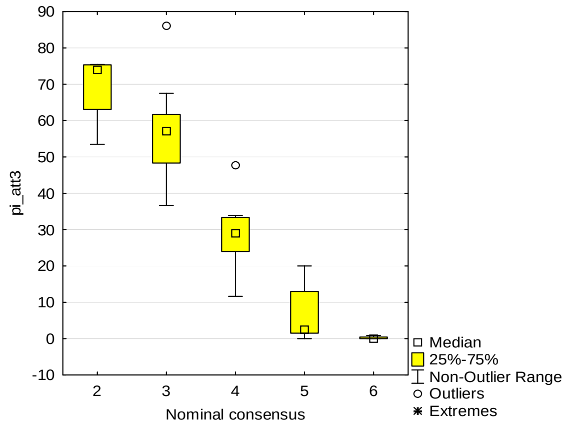

pt_att5
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

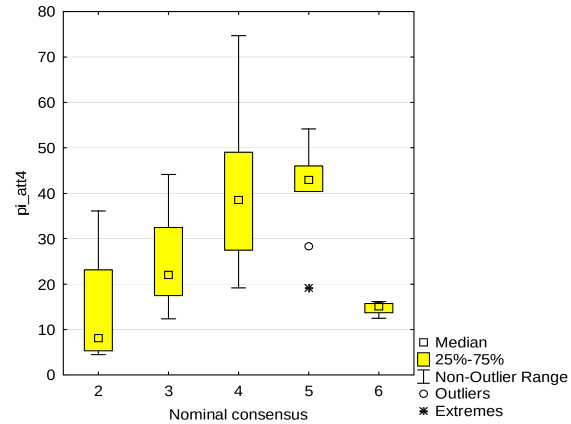

pt_att56
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

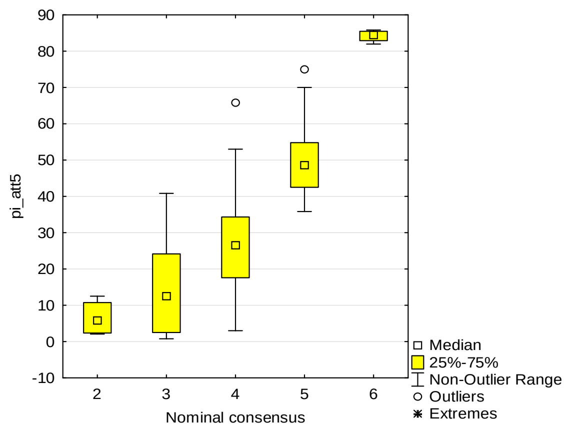

pt_att6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

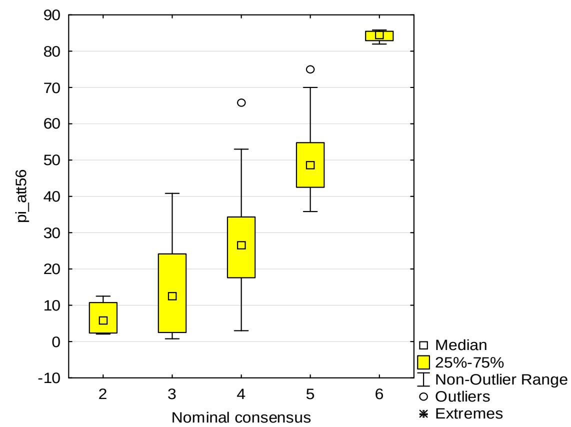

pi_att2
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

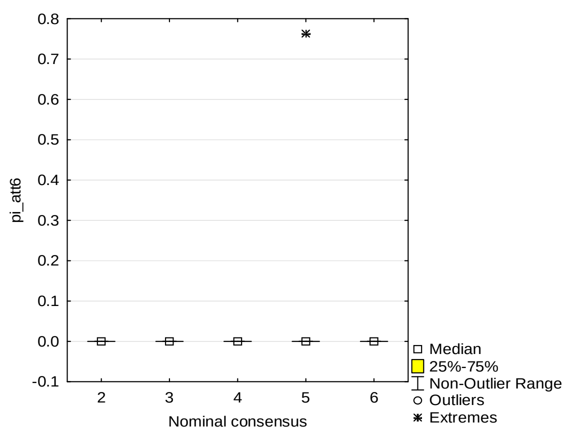

pi_att23
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

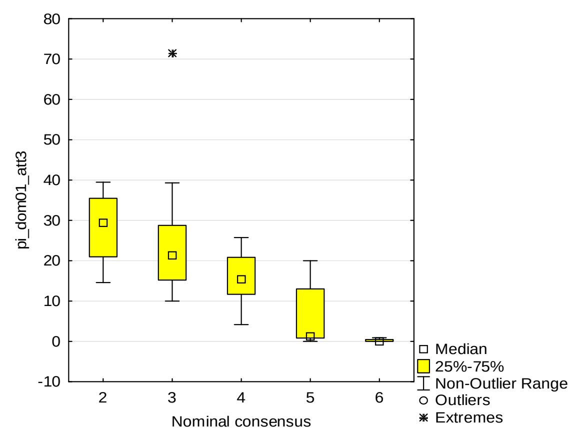

pi_att3
Nominal consensus
90
80
70
60
50
40
30
20
10
0
-10
2
3
4
5
6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

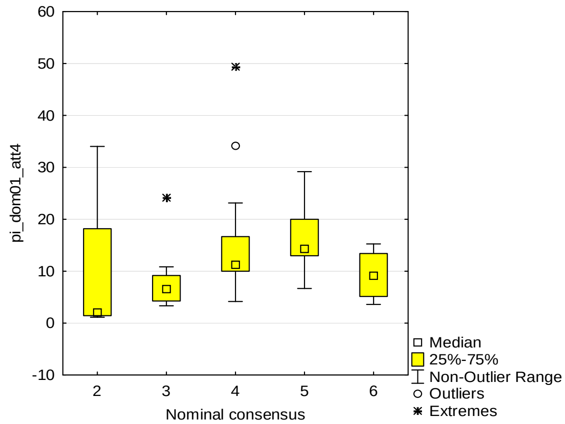

pi_att4
Nominal consensus
80
70
60
50
40
30
20
10
0
2
3
4
5
6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

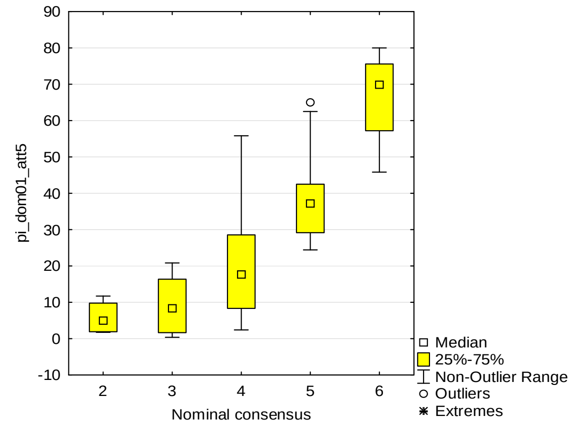

pi_att5
Nominal consensus
90
80
70
60
50
40
30
20
10
0
-10
2
3
4
5
6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

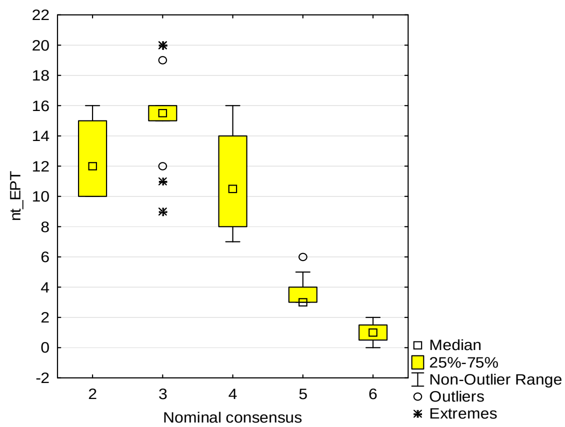

pi_att56
Nominal consensus
90
80
70
60
50
40
30
20
10
0
-10
2
3
4
5
6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

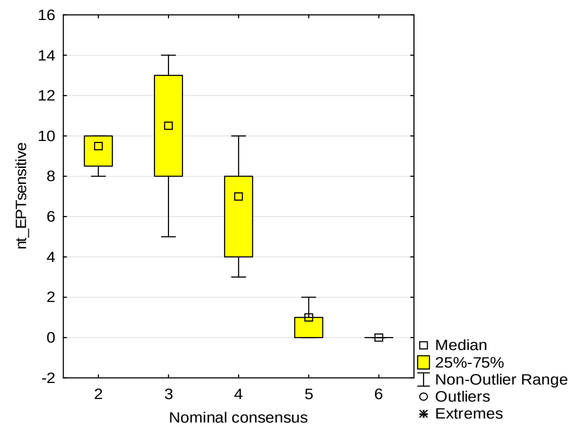

pi_att6
Nominal consensus
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
2
3
4
5
6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

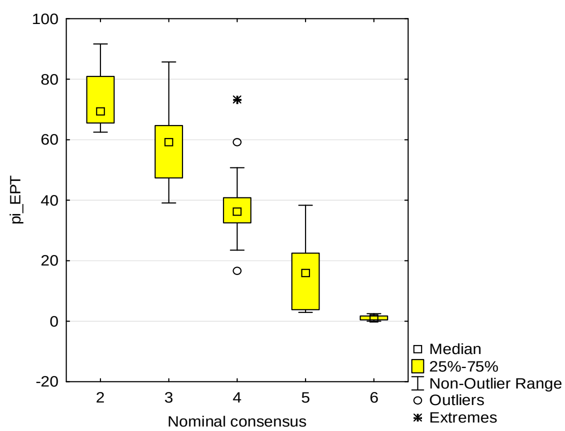

pi_dom01_att3
Nominal consensus
80
70
60
50
40
30
20
10
0
-10
2
3
4
5
6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

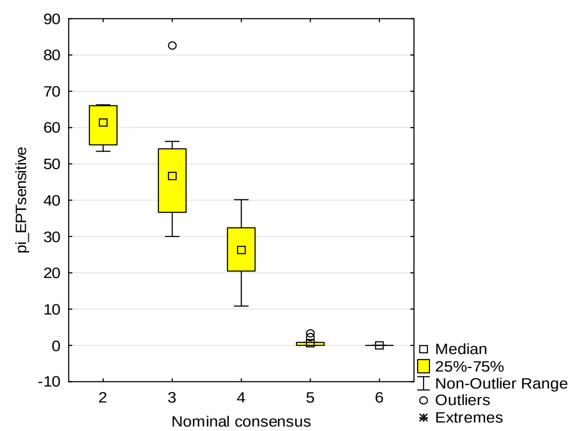

pi_dom01_att4
60
50
40
30
20
10
0
-10
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

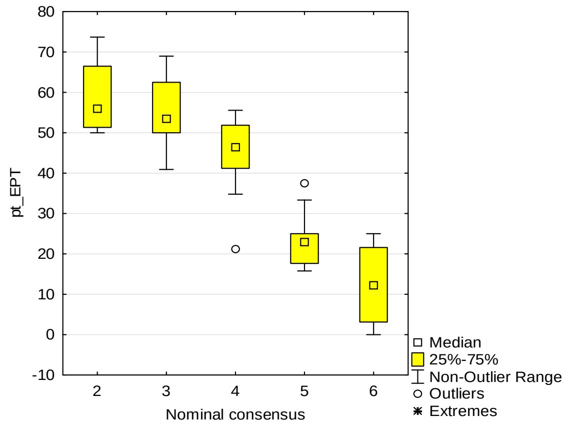

pi_dom01_att5
90
80
70
60
50
40
30
20
10
0
-10
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

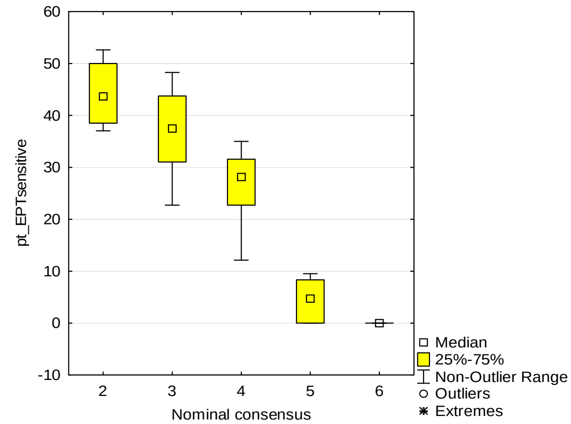

nt_EPT
22
20
18
16
14
12
10
8
6
4
2
0
-2
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

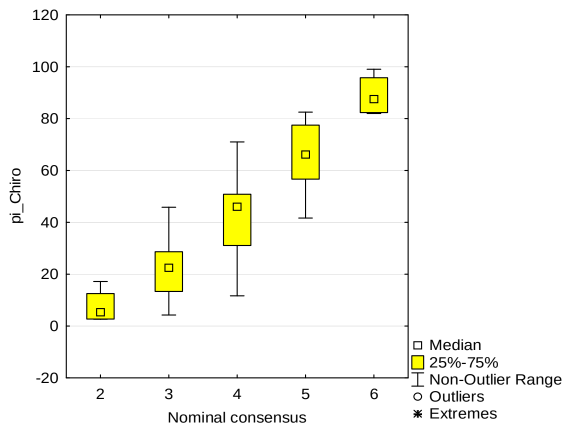

nt_EPTsensitive
16
14
12
10
8
6
4
2
0
-2
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

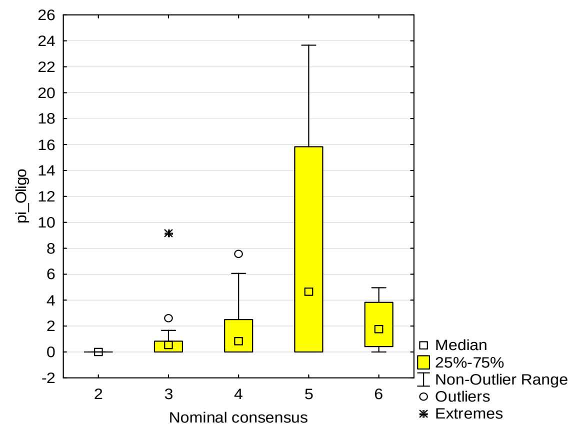

pi_EPT
100
80
60
40
20
0
-20
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

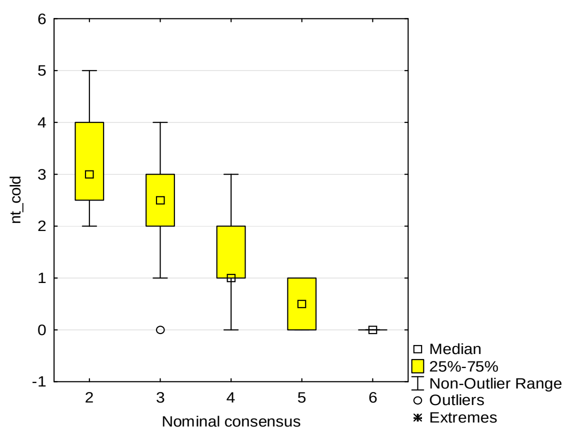

pi_EPTsensitive
90
80
70
60
50
40
30
20
10
0
-10
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

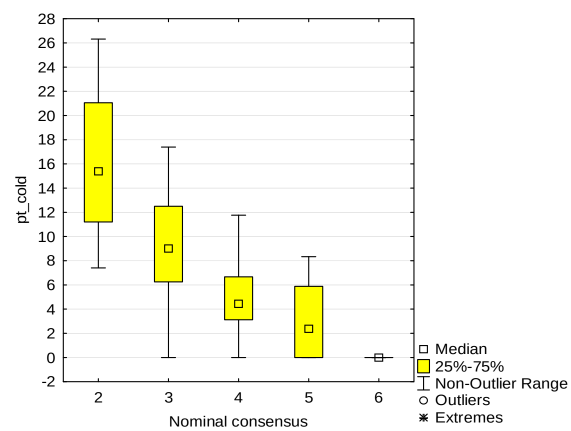

pt_EPT
80
70
60
50
40
30
20
10
0
-10
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

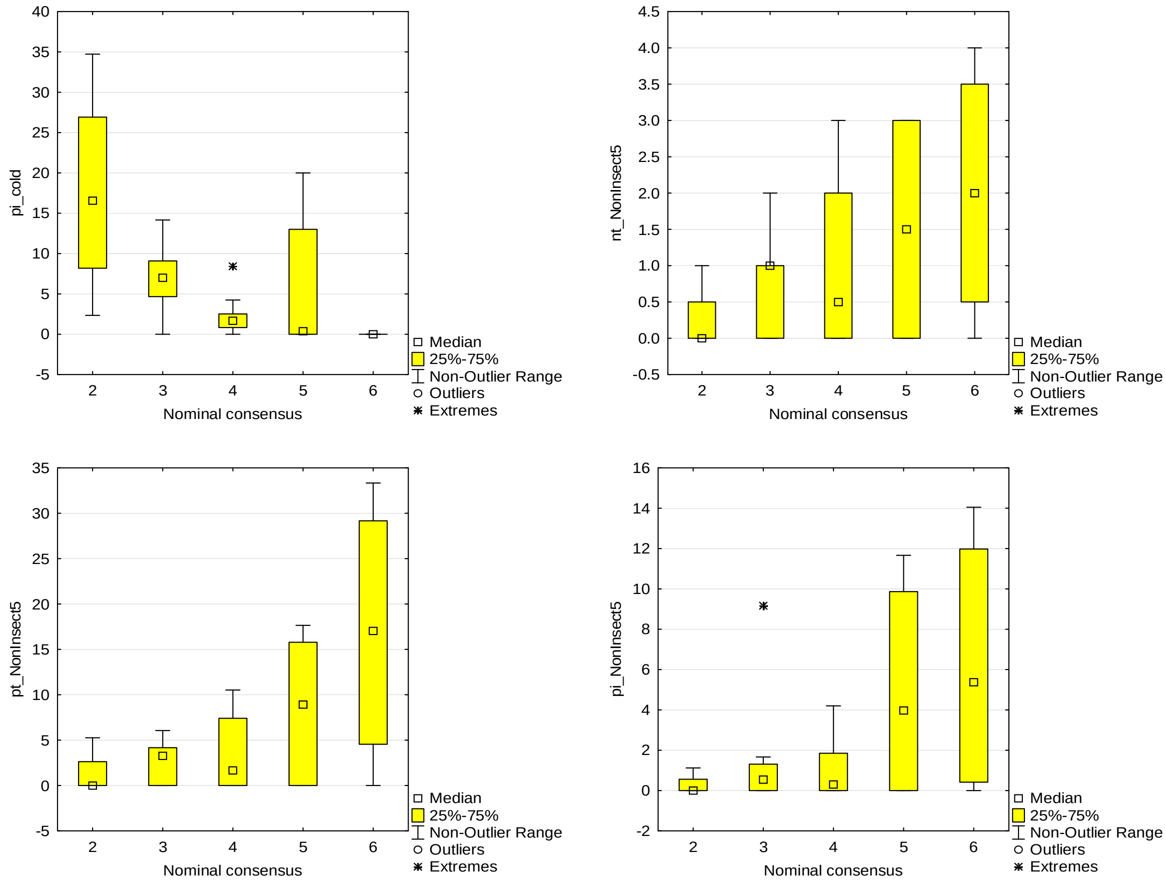

pt_EPTsensitive
60
50
40
30
20
10
0
-10
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_Chiro
120
100
80
60
40
20
0
-20
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_Oligo
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_cold
6
5
4
3
2
1
0
-1
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pt_cold
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_cold
nt_NonInsect5
pt_NonInsect5
pi_NonInsect5
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

Appendix J

BCG Level Assignments – Fish

Participants made BCG level assignments on 52 fish/salamander samples for the calibration exercise and 13 samples for the confirmation exercise. Samples were assessed using the scoring scale shown in Table J1.

Table J1. Scoring scale that was used for making BCG level assignments.

best	1
	1-
	2+
	2
	2-
	3+
	3
	3-
	4+
	4
	4-
	5+
	5
	5-
	6+
	6
worst	6-

Table J2 contains samples that were assessed during the calibration exercise and Table J3 has confirmation samples.

Table J2. BCG level assignments and sample information for fish/salamander samples that were assessed during the calibration exercise. BCG level assignments are as follows: Final=consensus BCG level (=the assignment made by the majority of participants); Best= the best BCG level assignment assigned by a participant (based on the scoring scale in Table J1); Worst=the worst BCG level assignment given by a participant. All BCG model assignments were within ½ level of the panelist consensus calls.

SITEYR	Exercise ID	Collection Year	Waterbody Name	Size Class	Area (mi2)	Panelist consensus			Primary model
						Final	Best	Worst	
WBPB201_1997	Samp008	1997	Piney Branch	small	0.5	3/4	3	4	3/4 tie
WBPB201_2012	Samp009	2012	Piney Branch	small	0.5	5	4	5	5
MBMB201_2007	Samp045	2007	Pennyfield Mainstem	small	0.6	6	6	6	6
LOCH-120-S-2009	Samp055	2009	BAISMAN RUN	small	0.7	2-	2	2-	2
LSCT103_2006	Samp013	2006	Churchill Trib.	small	0.7	4-/5+	4	5+	5
LSLS206_2012	Samp046	2012	Clarksburg Tributary	small	0.7	4+	3	4	4
NWLM301_2011	Samp019	2011	LongMeade Trib.	small	0.8	4	4	4-	4
BCBC211_1999	Samp043	1999	Bennett Creek	small	0.8	3-	3	4-	3
LIBE-209-A-2011	Samp058	2011	JOE BRANCH	small	0.8	3-	3	3-	3/4 tie
LPLP202_2011	Samp026	2011	Tanglewood Tributary	small	0.9	4+	3	4	4
LIBE-102-S-2002	Samp056	2002	TIMBER RUN	small	0.9	2	2+	2	2
LSTM202_2012	Samp029	2012	Little Seneca Creek - Ten Mile Creek	small	1.0	4+	3-	4	4
PBGS206_2012	Samp035	2012	Gum Springs Tributary	small	1.0	3	3	3	3
RKGR-119-S-2008	Samp049	2008	PATUXENT RIVER UT	small	1.1	4	4+	4	4
FURN-101-S-2006	Samp051	2006	PRINCIPIO CREEK UT1	small	1.1	3+	3+	3	3
LBSB201A_2012	Samp014	2012	Sopers Branch	small	1.2	3	3+	3-	3
PBRF206_1998	Samp006	1998	Right Fork	small	1.3	3	3	4+	3
PBRF206_2012	Samp007	2012	Right Fork	small	1.3	3-	3	4+	3
LPRG204_2010	Samp027	2010	Ednor Tributaries	small	1.3	5+	4	5	5
NWNW206A_2011	Samp033	2011	Northwest Branch - Right Fork	small	1.3	5+	5+	5	5
UPPR201A_2010	Samp038	2010	Upper Brighton Dam - Damascus Tributaries	small	1.3	3	3	3	3
PBGH208A_2012	Samp034	2012	Good Hope Tributary	small	1.4	3-	3-	3-	3
LBKT304_2008	Samp015	2008	Kingsley Trib.	small	1.5	3+	2-	3	3
PBHB210_2011	Samp036	2011	Hollywood Branch	medium	1.5	3	3	3-	3
URNB205_2012	Samp040	2012	Williamsburg Run	medium	1.6	4-	4	4-	4

Table J2. continued…

SITEYR	Exercise ID	Collection Year	Waterbody Name	Size Class	Area (mi2)	Panelist consensus			Primary model
						Final	Best	Worst	
WBPB204A_2012	Samp042	2012	Piney Branch	medium	2.0	4+	3-	4+	4
BCBC301_2003	Samp044	2003	Bennett Creek	medium	2.6	4+	4	4+	4
LRJB204_2012	Samp010	2012	Josephs Br.	medium	2.8	5	5	5	5
SCSC301_2011	Samp037	2011	Upper Sligo Creek Mainstem	medium	3.1	5	5	5	5
UPPR301_2010	Samp016	2010	Pat. River	medium	3.2	3+	2-	3+	3
HWGT204_2010	Samp022	2010	Gregg Road Tributary	medium	3.2	4+	4+	4	4
LSTM302_2012	Samp075	2012	Little Seneca Creek - Ten Mile Creek	medium	3.2	4	4+	4-	4
URMC304_2012	Samp039	2012	Upper Rock Creek - Mill Creek	medium	3.2	4-	4	4-	4
HWJC301_2010	Samp024	2010	James Creek	medium	3.3	4	4	4-	4
LSTM303B_2012	Samp031	2012	Little Seneca Creek - Ten Mile Creek	medium	3.5	4-	4-	5+	4
NWBP205_2011	Samp032	2011	Bel Pre	medium	3.6	5	5+	5	5
LRTB203C_2012	Samp028	2012	Turkey Branch	medium	3.8	4	3-	4-	4
LSTM304_2012	Samp003	2012	Ten Mile (gage)	medium	4.4	4+	3	4-	3/4 tie
DEER-228-R-2004	Samp052	2004	STOUT BOTTLE BRANCH	medium	4.4	3	3+	3	3
NEAS-103-R-2001	Samp053	2001	WEST BRANCH	medium	4.7	3	3+	3-	3
LFLF301C_2007	Samp012	2007	Little Falls	medium	4.7	6	6	6	6
HBHB302_2010	Samp021	2010	Mount Nebo Tributaries	medium	5.8	5	5	5-	5
JONE-315-S-2003	Samp048	2003	NORTH BRANCH JONES FALLS	medium	5.9	4+	3-	4	4
LIBE-251-A-2007	Samp059	2007	DEEP RUN	medium	7.1	3-	3	4+	3
ATKI-217-R-2004	Samp057	2004	EAST BRANCH	medium	7.2	3-	3-	3-	3
SBPA-302-A-2008	Samp050	2008	PINEY BRANCH	larger	8.0	3	3+	3	3
HWHW308B_2010	Samp023	2010	Upper Hawlings River	larger	9.6	3	3	3-	3
LMON-322-R-2003	Samp054	2003	LITTLE BENNETT CREEK	larger	9.8	4	4+	4	4
DEER-247-A-2007	Samp047	2007	LITTLE DEER CREEK	larger	10.0	3+	2	3-	3

Table J2. continued…

SITEYR	Exercise ID	Collection Year	Waterbody Name	Size Class	Area (mi2)	Panelist consensus			Primary model
						Final	Best	Worst	
NEAS-201-R-2001	Samp061	2001	LITTLE NORTHEAST CREEK	larger	12.0	3+	2-	3	3
LMLM313_2010	Samp025	2010	Lower Little Monocacy - Dickerson Tributaries	larger	13.4	3-	3	3-	3
LOCH-305-R-2002	Samp060	2002	BLACKROCK RUN	larger	13.9	3	3+	3	3

Table J3. BCG level assignments and sample information for fish/salamander samples that were assessed during the confirmation exercise. BCG level assignments are as follows: Final=consensus BCG level (=the assignment made by the majority of participants); Best= the best BCG level assignment assigned by a participant (based on the scoring scale in Table H1); Worst=the worst BCG level assignment given by a participant. Samples are highlighted in yellow if the consensus call from the panelists is different from the primary call from the model.

SITEYR	Exercise ID	Collection Year	Waterbody Name	Size Class	Area (mi2)	Panelist consensus			Primary model
						Final	Best	Worst	
LSLS206_2013	Samp064	2013	Clarksburg Tributary	small	0.75	3-	3	4	4
LSTM203_2012	Samp069	2012	Little Seneca Creek - Ten Mile Creek	small	0.77	4+	3	5-	4
LSTM201_2012	Samp065	2012	Little Seneca Creek - Ten Mile Creek	small	0.95	4	4	5+	4
LSTM202_2013	Samp068	2013	Little Seneca Creek - Ten Mile Creek	small	0.95	3-	3	4	3
NWBF202_2011	Samp081	2011	Northwest Branch - Batchellors Run	small	0.97	6	5	6	6
LRLB202_2008	Samp087	2008	Luxmanor Branch	small	1.22	6	5	6	6
PBGH208A_2010	Samp083	2010	Good Hope Tributary	small	1.3	3	3+	3-	3
LPPR206_2010	Samp063	2010	Ashland Tributary	medium	1.6	5	4	5	5
GSGB208_2006	Samp062	2006	Upper Great Seneca Creek - Goshen Branch	medium	2.7	3	3+	4+	3
URRC301A_2012	Samp085	2012	Upper Rock Creek	medium	3.15	4+	3+	4	4
LSTM303B_2013	Samp079	2013	Little Seneca Creek - Ten Mile Creek	medium	3.47	4+	3	4	4
PBPB305C_2006	Samp084	2006	Paint Branch - Upper Mainstem	medium	7.3	3	3+	3	3
URRC403_2012	Samp086	2012	Lake Needwood Mainstem	larger	15.2	3/4	2-	4	3/4 tie

Appendix K

Box Plots of All Metrics –Fish

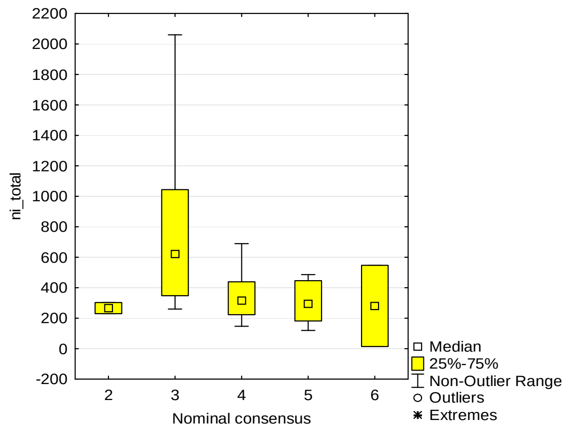
Box plots were generated to examine the distributions of metric values across BCG levels. Table K1 contains descriptions of the metric codes that are on the y-axes of the plots.

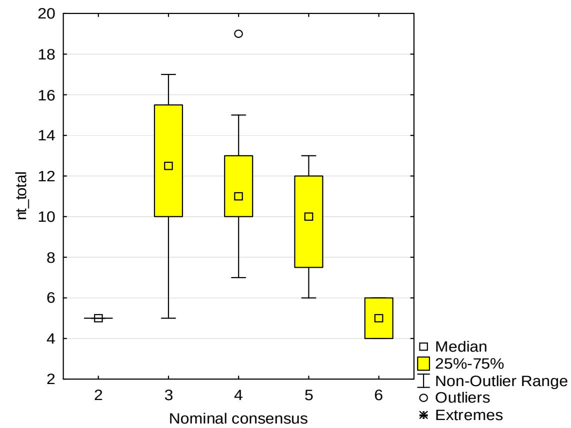
TableK1. Descriptions of the metric codes that are on the y-axes of the box plots.

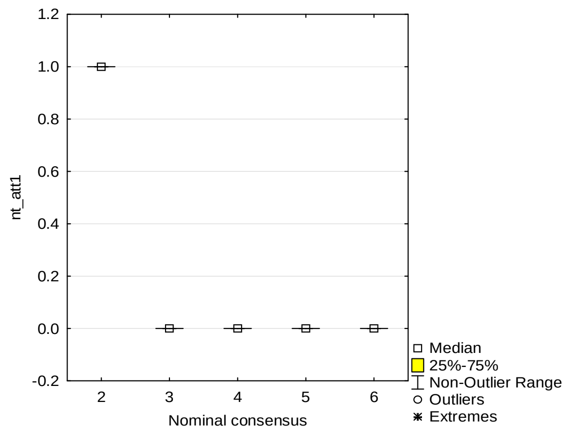
Metric code	Description
ni_total	number of total individuals
nt_total	number of total taxa
nt_att1	number of attribute 1 taxa
nt_att12	number of attribute 1 + 2 taxa
nt_att2	number of attribute 2 taxa
nt_att123	number of attribute 1 + 2 + 3 taxa
nt_att3	number of attribute 3 taxa
nt_att4	number of attribute 4 taxa
nt_att5	number of attribute 5 taxa
nt_att56t	number of attribute 5 + 6t taxa
nt_att6	number of attribute 6 (6i Or 6m Or 6t) taxa
nt_att6t	number of attribute 6t taxa
nt_att6i	number of attribute 6i taxa
nt_att10	number of attribute 10 taxa
pt_att12	percent attribute 1 + 2 taxa
pt_att2	percent attribute 2 taxa
pt_att123	percent attribute 1 + 2 + 3 taxa
pt_att3	percent attribute 3 taxa
pt_att4	percent attribute 4 taxa
pt_att5	percent attribute 5 taxa
pt_att56t	percent attribute 5 + 6t taxa
pt_att6	percent attribute 6 (6i Or 6m Or 6t) taxa
pt_att6i	percent attribute 6i taxa
pt_att10	percent attribute 10 taxa
pi_att1	percent attribute 1 individuals
pi_att12	percent attribute 1 + 2 individuals
pi_att2	percent attribute 2 individuals
pi_att123	percent attribute 1 + 2 + 3 individuals
pi_att3	percent attribute 3 individuals
pi_att4	percent attribute 4 individuals
pi_att5	percent attribute 5 individuals
pi_att56t	percent attribute 5 + 6t individuals
pi_att6	percent attribute 6 individuals
pi_att6t	percent attribute 6t individuals
pi_att6i	percent attribute 6i individuals
pi_att10	percent attribute 10 individuals

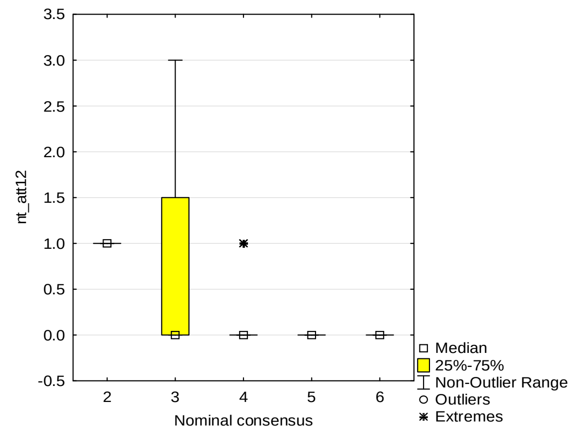
TableK1. continued…

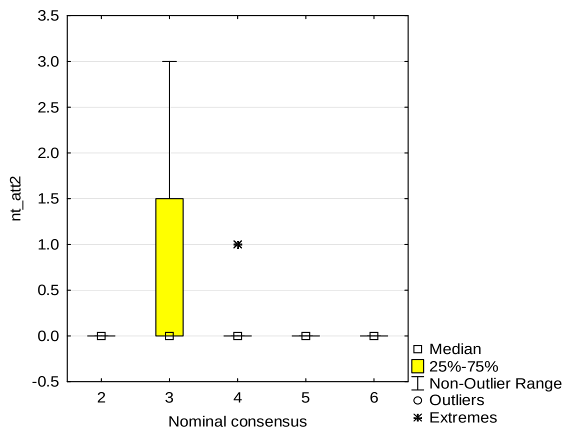
Metric code	Description
pi_dom01_att4	percent individuals - domininant attribute 4 taxon
pi_dom01_att5	percent individuals - domininant attribute 5 taxon
pi_dom01_att56t	percent individuals - domininant attribute 5 + 6t taxon
nt_TopPred	number of top predator taxa
nt_SensCypr	number of mid-water cyprinid taxa (notropis, luxilus, clinostomus and cyprinella, minus swallowtail shiners)
pt_TopPred	percent top predator taxa
pt_SensCypr	percent mid-water cyprinid taxa (notropis, luxilus, clinostomus and cyprinella, minus swallowtail shiners)
pi_TopPred	percent top predator individuals
pi_SensCypr	percent mid-water cyprinid taxa (notropis, luxilus, clinostomus and cyprinella, minus swallowtail shiners)
nt_SensSalamander	number of sensitive (att2) salamander taxa (northern dusky or northern red)
nt_Salamander	number of salamander taxa

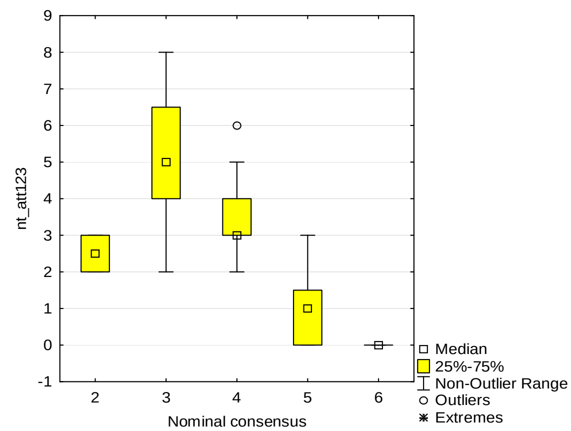

ni_total
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
-200
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

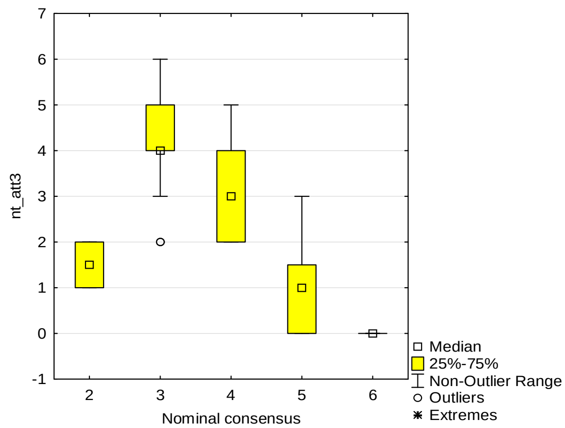

nt_total
20
18
16
14
12
10
8
6
4
2
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

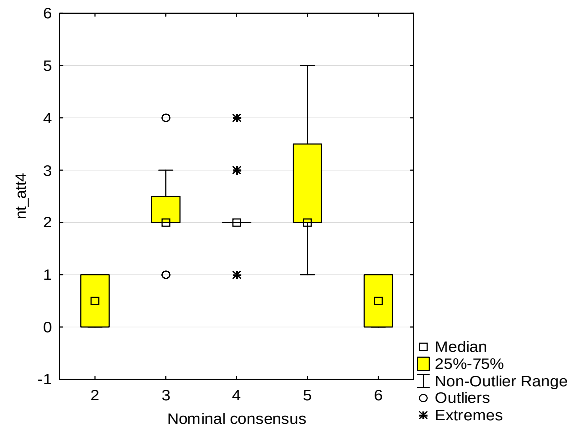

nt_att1
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

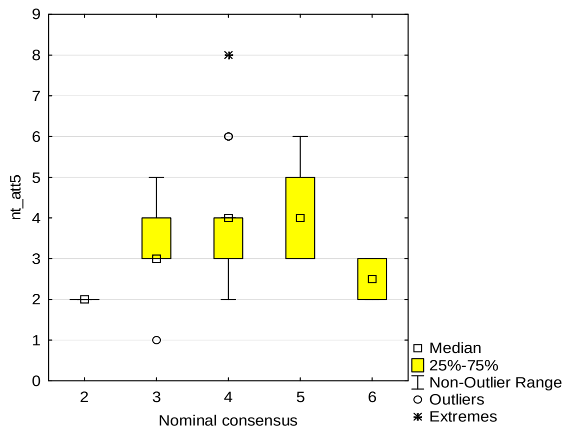

nt_att12
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

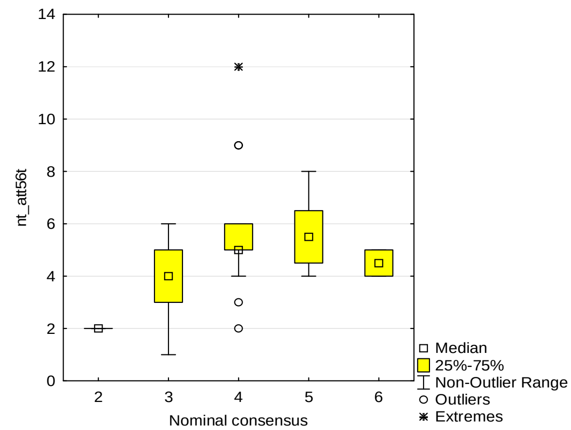

nt_att2
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

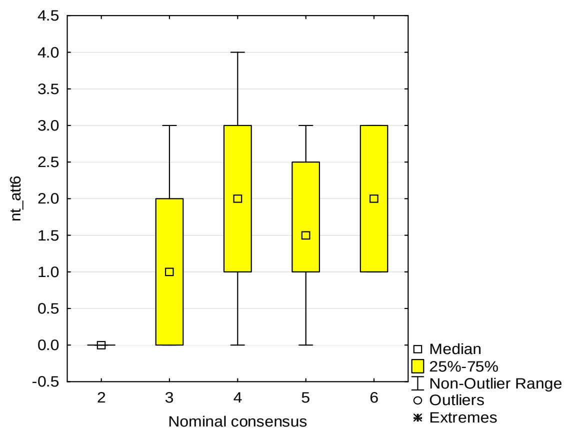

nt_att123
9
8
7
6
5
4
3
2
1
0
-1
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

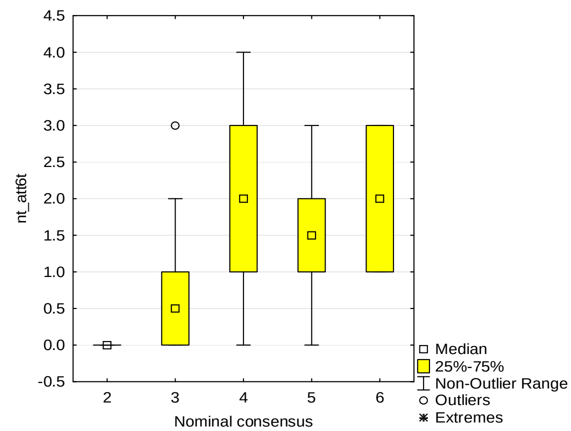

nt_att3
7
6
5
4
3
2
1
0
-1
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

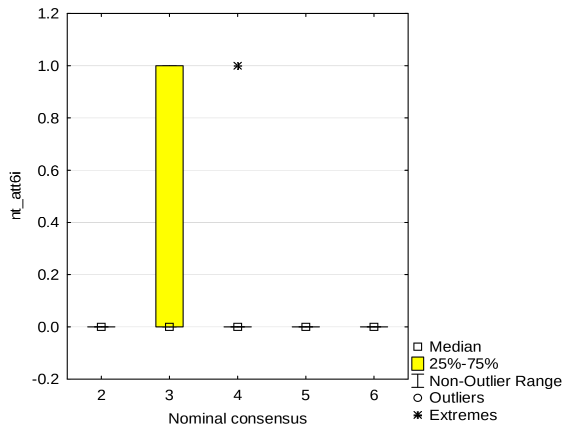

nt_att4
6
5
4
3
2
1
0
-1
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

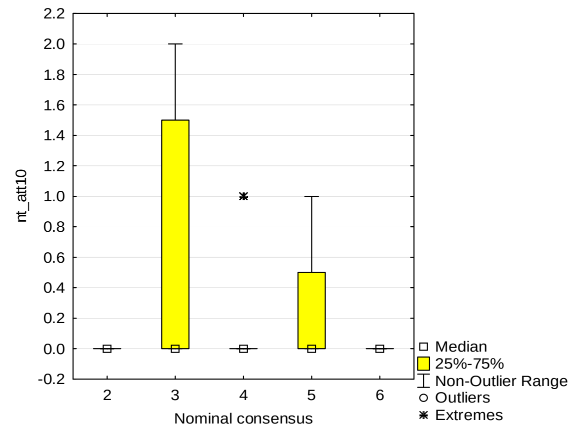

nt_att5
9
8
7
6
5
4
3
2
1
0
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

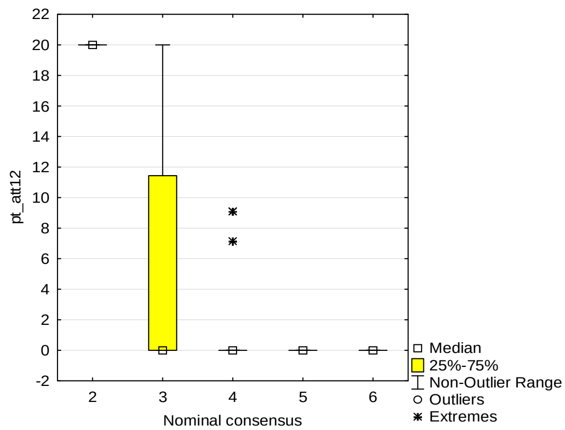

nt_att56t
14
12
10
8
6
4
2
0
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

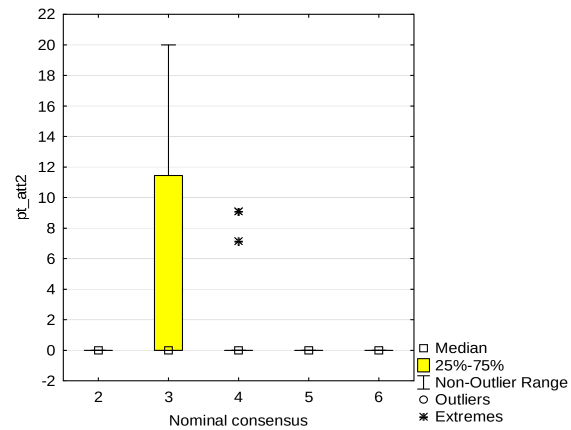

nt_att6
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

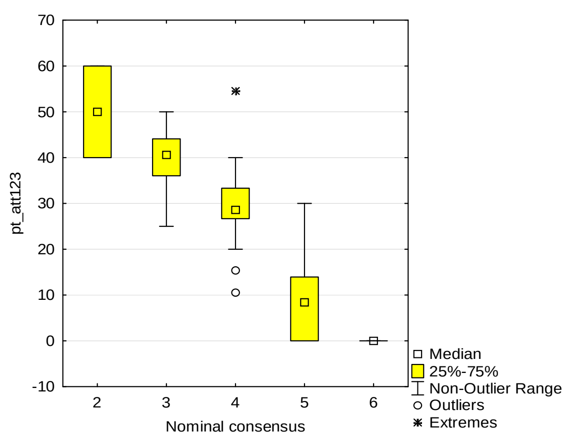

nt_att6t
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

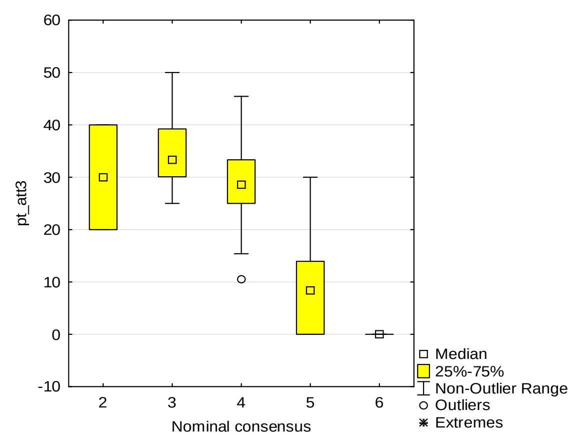

nt_att6i
Nominal consensus
2 3 4 5 6
1.2 1.0 0.8 0.6 0.4 0.2 0.0 -0.2
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

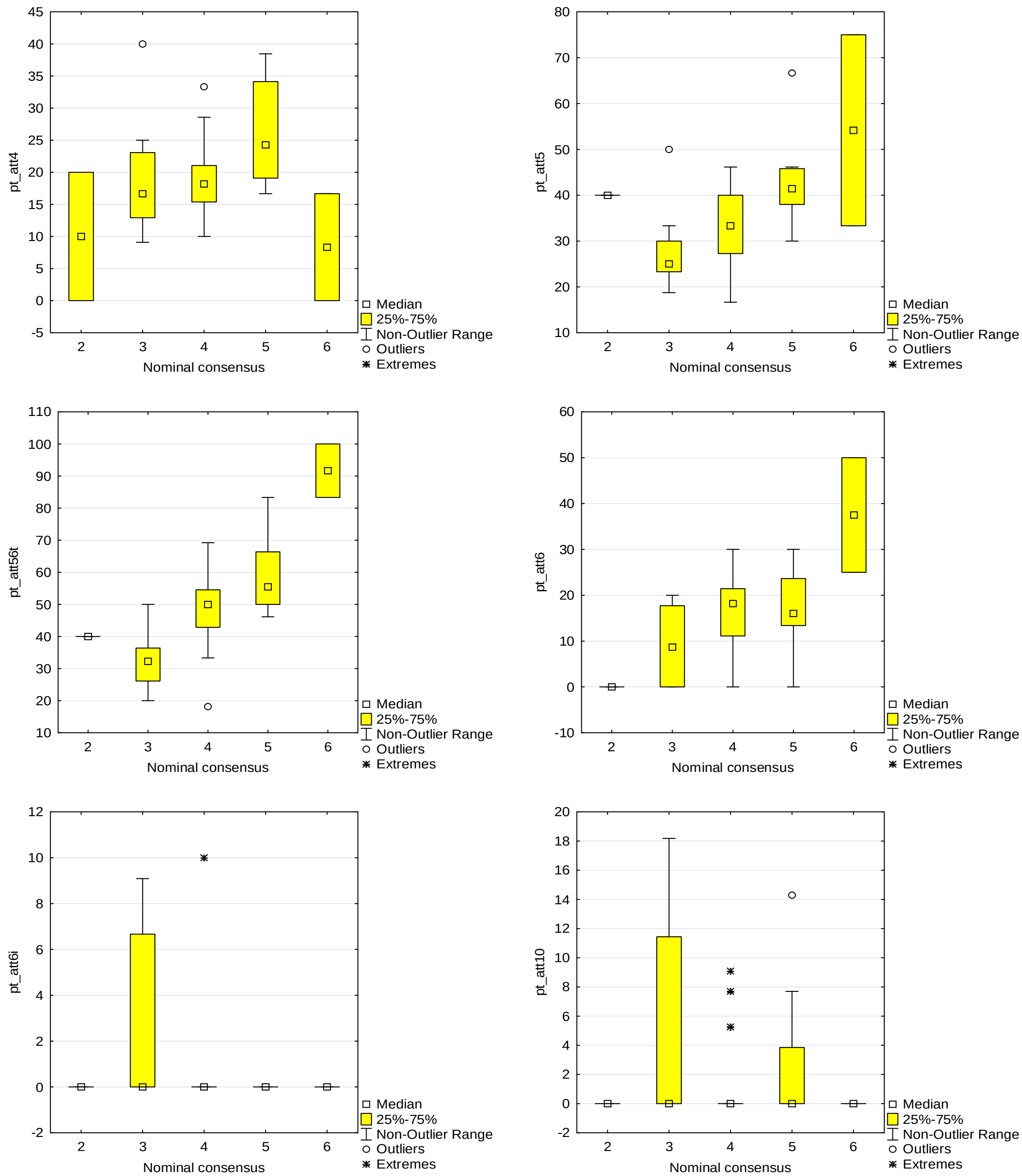

nt_att10
Nominal consensus
2 3 4 5 6
2.2 2.0 1.8 1.6 1.4 1.2 1.0 0.8 0.6 0.4 0.2 0.0 -0.2
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

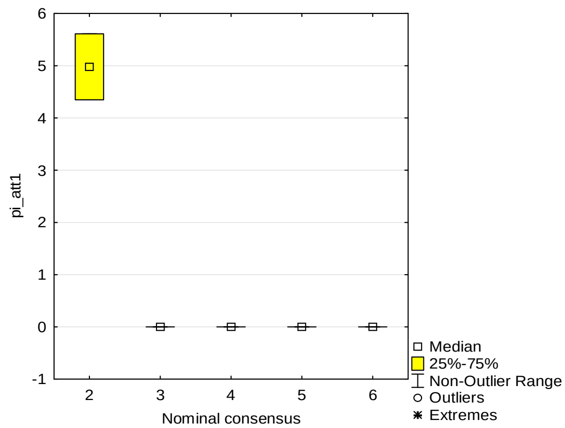

pt_att12
Nominal consensus
2 3 4 5 6
22 20 18 16 14 12 10 8 6 4 2 0 -2
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

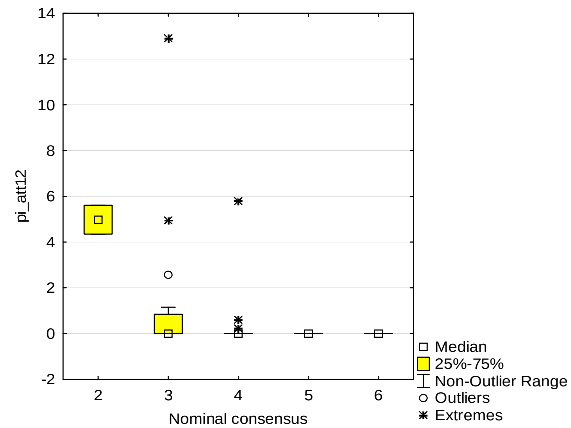

pt_att2
Nominal consensus
2 3 4 5 6
22 20 18 16 14 12 10 8 6 4 2 0 -2
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

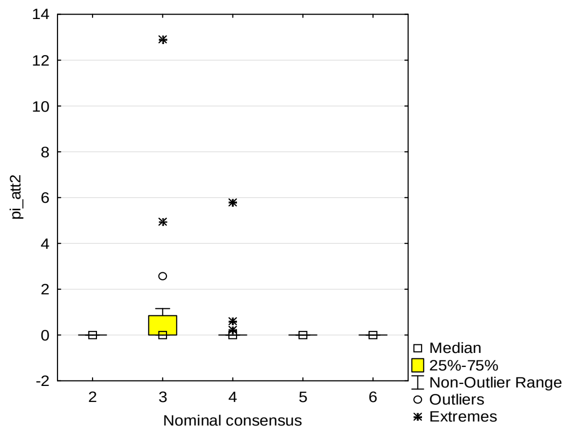

pt_att123
Nominal consensus
2 3 4 5 6
70 60 50 40 30 20 10 0 -10
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

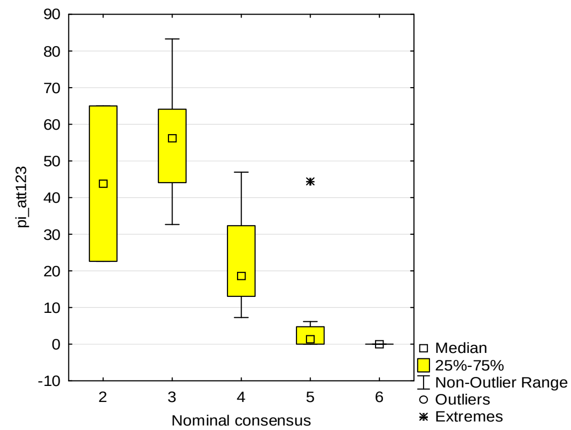

pt_att3
Nominal consensus
2 3 4 5 6
60 50 40 30 20 10 0 -10
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

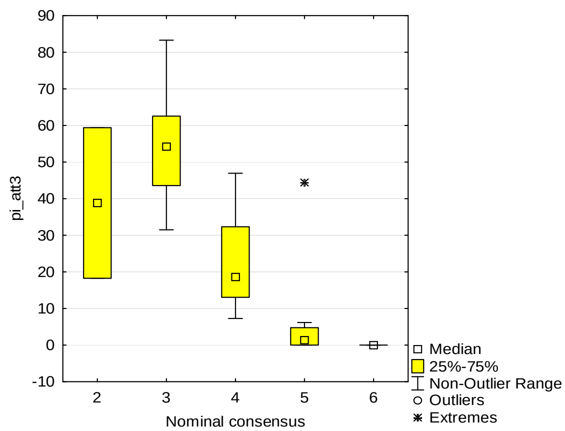

pt_att4
pt_att5
pt_att56t
pt_att6
pt_att6i
pt_att10
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

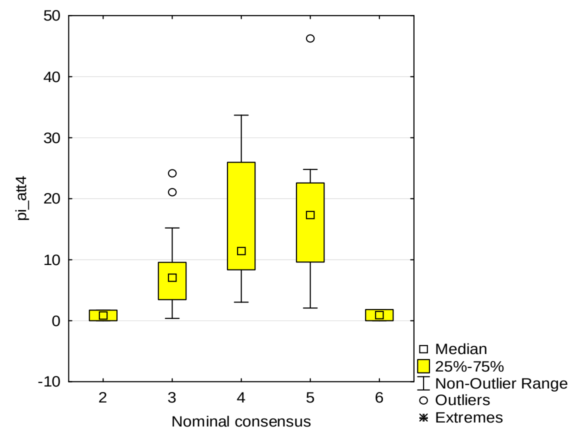

pi_att1
Nominal consensus
6
5
4
3
2
1
0
-1
2 3 4 5 6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

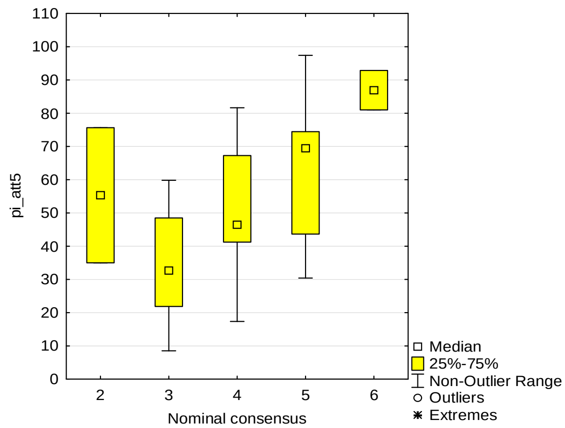

pi_att12
Nominal consensus
14
12
10
8
6
4
2
0
-2
2 3 4 5 6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

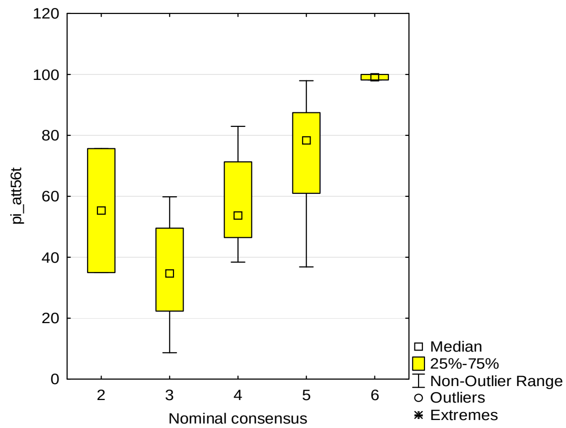

pi_att2
Nominal consensus
14
12
10
8
6
4
2
0
-2
2 3 4 5 6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

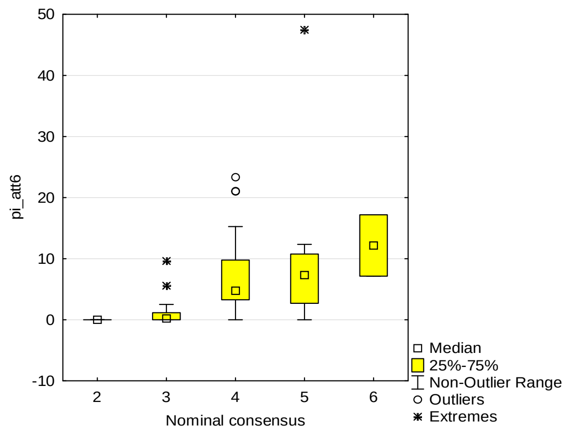

pi_att123
Nominal consensus
90
80
70
60
50
40
30
20
10
0
-10
2 3 4 5 6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

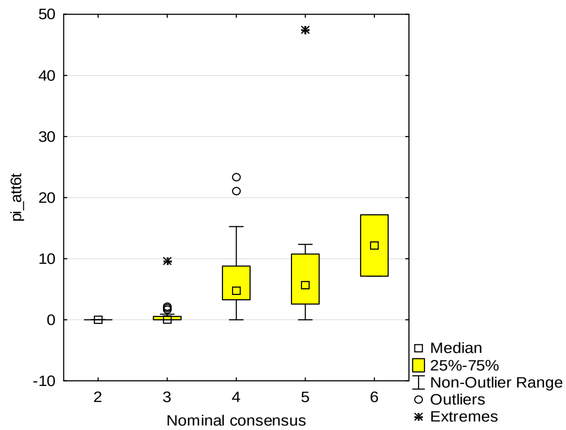

pi_att3
Nominal consensus
90
80
70
60
50
40
30
20
10
0
-10
2 3 4 5 6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

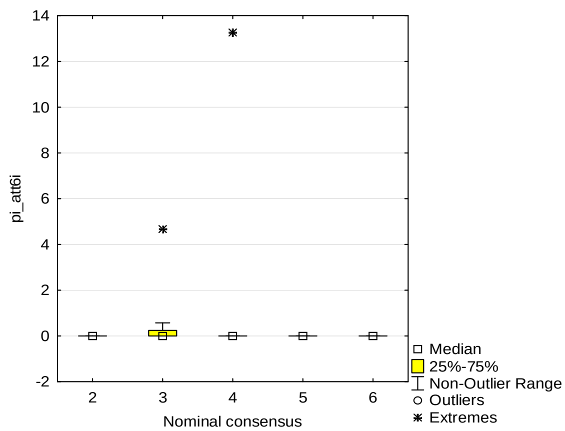

pi_att4
Nominal consensus
50
40
30
20
10
0
-10
2 3 4 5 6
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

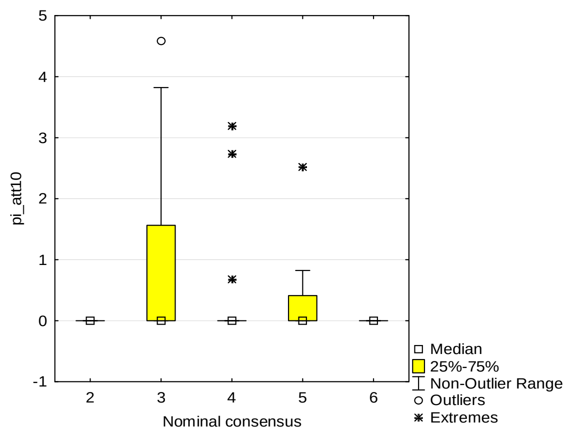

pi_att5
110
100
90
80
70
60
50
40
30
20
10
0
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

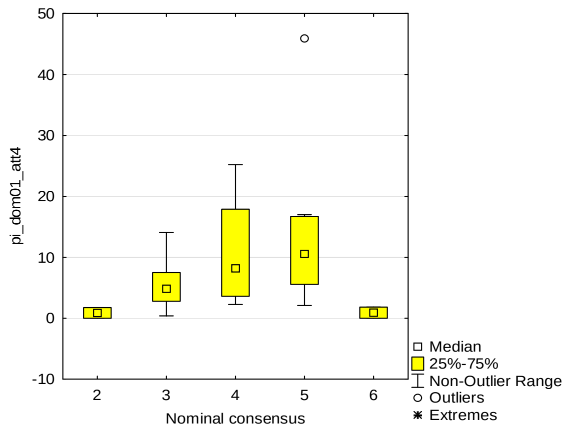

pi_att56t
120
100
80
60
40
20
0
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

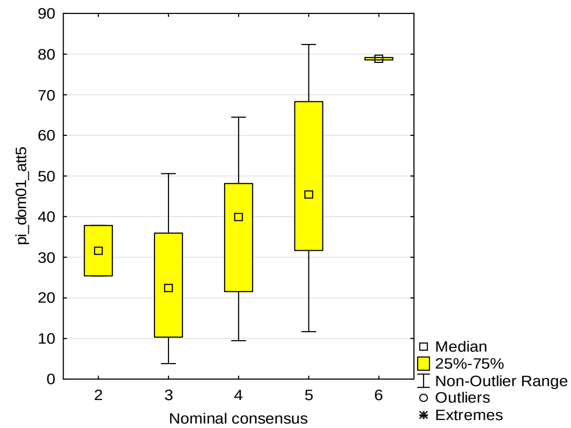

pi_att6
50
40
30
20
10
0
-10
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

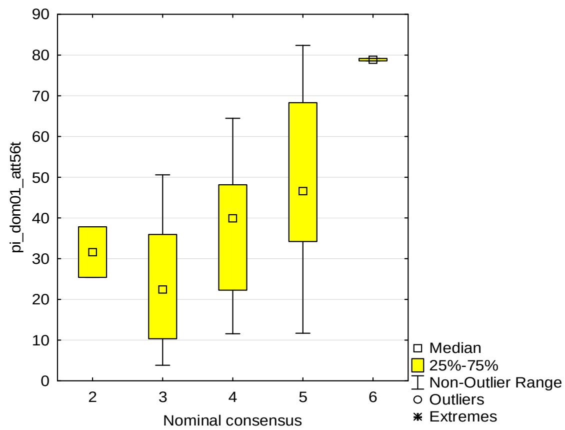

pi_att6t
50
40
30
20
10
0
-10
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

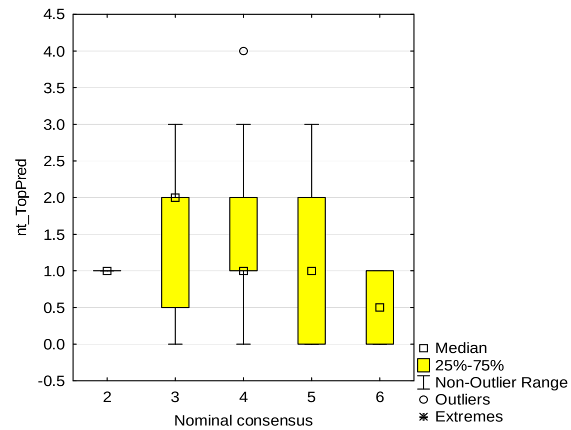

pi_att6i
14
12
10
8
6
4
2
0
-2
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

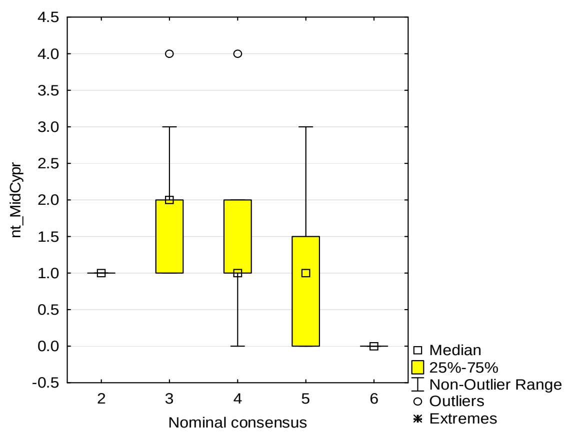

pi_att10
5
4
3
2
1
0
-1
2
3
4
5
6
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

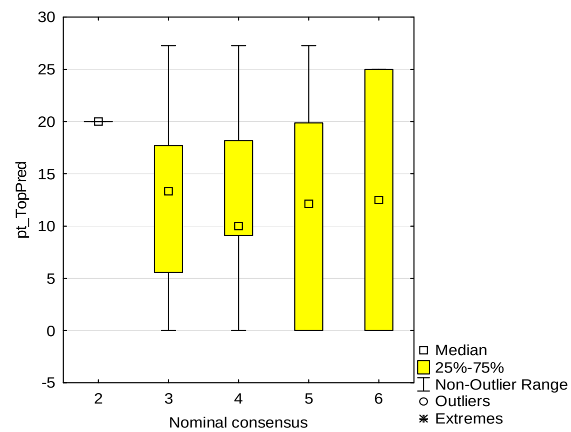

pi_dom01_att4
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

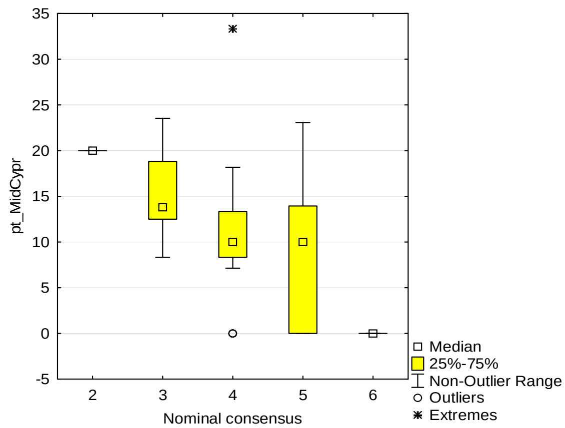

pi_dom01_att5
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


pi_dom01_att56t
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

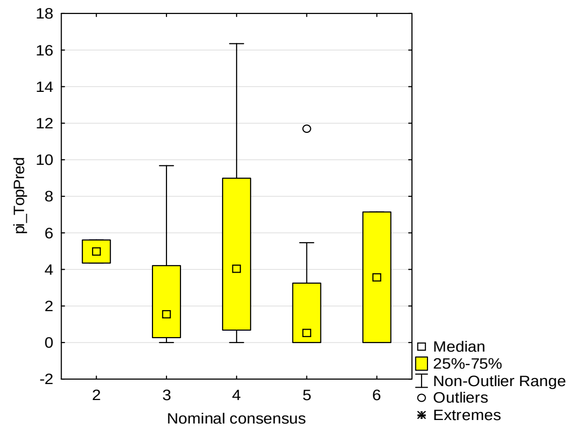

nt_TopPred
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes


nt_MidCypr
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes

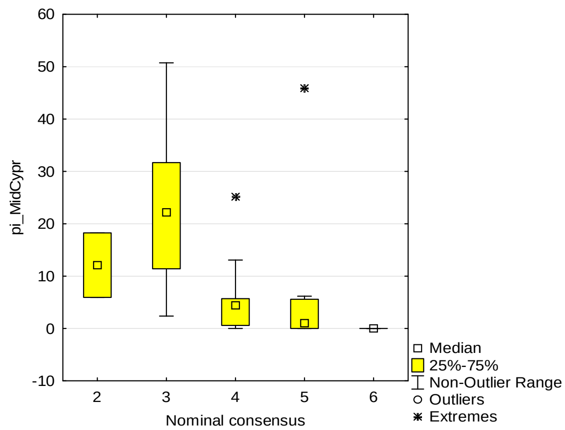

pt_TopPred
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



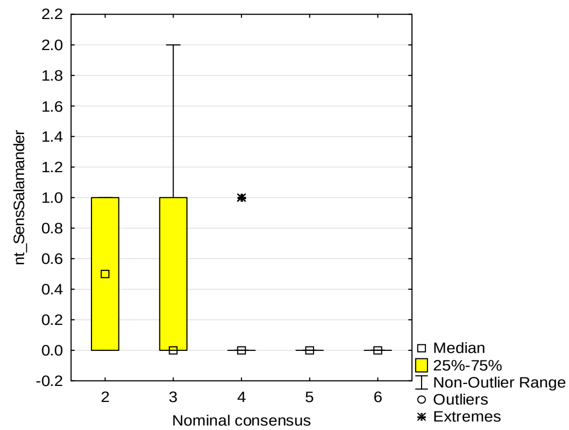
pt_MidCypr
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



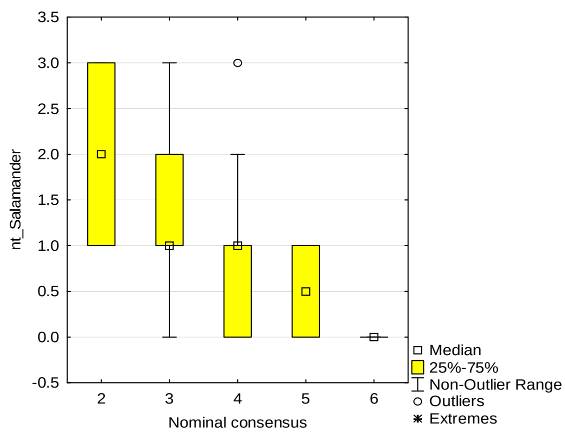
pi_TopPred
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



pi_MidCypr
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



nt_SensSalamander
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes



nt_Salamander
Nominal consensus
Median
25%-75%
Non-Outlier Range
Outliers
Extremes